Video-Games for Treating the Weaker Upper Extremity of Individuals with Subacute Stroke: A Pilot Randomized Controlled Trail

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Abstract

Background. Video-games (VG) are currently being used in rehabilitation to improve the weaker upper extremity (UE) following stroke. Typically they are employed as an adjunct to standard therapy and one type of console is used. **Objectives.** 1) To assess the feasibility of solely using VG to treat the weaker UE, and 2) to assess the effectiveness of VG compared to traditional therapy to improve function, motor ability and increase the use of the weaker UE in performing daily activities post-stroke. **Methods.** Twenty participants with mild-moderate UE weakness due to stroke were allocated to receive occupational therapy (three 1-hour sessions/week for 4-weeks) through playing VG or through traditional intervention. The Fugl-Meyer Motor Assessment, Action Research Arm Test, grip strength test and wrist accelerometers were administered pre- and post-intervention by assessors blind to group allocation. **Results.** Participants were able to play VG with their weaker UE. A significant improvement in motor ability [Z= -2.5; p=0.012 (VG), Z= -1.99; p=0.04 (traditional)] and functional ability [Z= -2.2; p=0.024 (VG), Z= -2.25; p=0.02 (traditional)] were found in both groups. Grip strength improved significantly only for participants who played VG. The use of the weaker arm in daily activities did not increase in either group. **Conclusions.** It is feasible and effective to use VG to treat the weaker UE at the subacute stage post-stroke. Further research is recommended.

Background

The recovery of the weaker upper extremity (UE) post-stroke is known to be limited and unsatisfactory. Many individuals remain with a nonfunctional weaker UE (Broeks, Lankhorst, Rumping, & Prevo, 1999; Kwakkel, Kollen, van der Gron, & Prevo, 2003; Wade, Langton-Hewer, Wood, Skilbeck, & Ismail, 1983), which is devastating (Barker & Brauer, 2005) and has a negative impact on their health-related-quality-of-life (Nichols-Larsen, Clark, Zeringue, Greenspan, & Blanton, 2005). Rather than relying only on simple, repetitive limb movements for the stroke affected UE, clinicians seek strategies to incorporate movement within the performance of meaningful, task-oriented activities, and thus enhance brain reorganization (Jang, Kim, Cho, Lee, Park, & Kwon, 2003; Plautz, Milliken, & Nudo, 2000). However, in the early stages following stroke, many individuals have inadequate UE movement (Lang, Wagner, Edwards, & Dromerick, 2007). Therefore it is often not feasible for them to perform meaningful, task-oriented activities.

Intervention studies have utilized different video-game (VG) consoles, usually focusing on one type of console for the intervention. The Nintendo Wii™ (Wii) with a wireless remote, the Sony PlayStation 2 EyeToy™ (EyeToy) video capture system that projects the user's image into a virtual game, and the new Microsoft Xbox with the 3-D Kinect sensor have all been used to encourage active movement of the UE in an enjoyable manner during stroke rehabilitation.

Individuals with and without stroke were observed to perform a myriad of

UE movements while playing Wii and EyeToy games (Peters, McPherson, Fletcher, McClenaghan, & Fritz, 2013). When these movements were quantified via wrist accelerometers (Kam, Struzik, Jarus, & Rand, 2012; Rand, Givon, Weingarden, Nota, & Zeilig, 2014) these movements were found to be performed at different intensities depending on the VG console used (Neil, Ens, Pelletier, Jarus, & Rand, 2013; Peters et al., 2013). VG were found to elicit more purposeful UE movement repetitions at higher intensities within a 1-hour session as opposed to traditional therapy (Rand et al., 2014). VG increase the intensity of the treatment session (more repetitions within a given time period and increased willingness of participants to continue for longer sessions) and therefore they might promote motor recovery.

Commercially available VG consoles have been adapted for use as therapeutic tools with the potential to improve the weaker UE during stroke rehabilitation. VG encourage purposeful movements while offering a stimulating and motivating environment for the user (Flynn, Palma, & Bender, 2007; Rand, Kizony, & Weiss, 2008). Providing VG as an adjunct to standard rehabilitative care for individuals undergoing rehabilitation following subacute stroke (Lee, 2013; Saposnik et al., 2010; Yavuzer, Senel, Atay, & Stam, 2008) have led to greater UE improvement compared to participants not receiving alternative UE treatment (i.e., watching VG [Yavuzer et al., 2008] and/or playing social games [Saposnik et al., 2010]). A significant improvement in motor ability and function and in the daily use of the UE was also found in seven individuals with stroke who participated in 10 1-hour sessions playing the Wii and augmented by home practice (Mouawad, Doust, Max, & McNulty, 2011). The effectiveness of playing Microsoft Xbox-Kinect games in addition to traditional therapy to the recovery of the weaker UE post-stroke has been reported when compared to traditional therapy at the subacute (Lee, 2013) and chronic stages (Sin & Lee, 2013). However, it is unclear if this improvement was due to the Xbox Kinect or greater total training time.

In order to establish the effectiveness of VG as an intervention tool for rehabilitation, it is essential to compare it to traditional UE therapy. Moreover, since the other studies added VG to standard care, it would be important to determine the effectiveness of using VG alone in encouraging UE movement during this stage. Therefore, this pilot randomized controlled trial aimed to: 1) assess the feasibility of using VGs alone as a tool for treating the weaker UE, and 2) assess the effectiveness of using VG compared to traditional therapy for improving motor and functional ability and increase the daily-use of the weaker UE. We hypothesized that it will be a feasible to solely use VG as a tool to encourage UE movements of individuals admitted to stroke rehabilitation. Furthermore, we hypothesized that it would be more effective than traditional therapy in enhancing their motor and functional ability and increasing participants' UE daily-use of the weaker upper extremity, due to the unique attributes of VG..

Methods

Participants

Consecutive adults admitted for stroke rehabilitation due to a stroke that had occurred within the previous 10 weeks, could sit without support for at least 10 seconds, demonstrating mild to moderate UE weakness (scores ranging from 28-90 points on the Motricity Index [MI; Bohannon, 1999; Collin & Wade, 1990] a screening tool to assess UE motor impairment) and who gave their consent were included in the study. Exclusion criteria included a significant cognitive impairment (score ≥ 15/30 points on the Mini Mental State Examination [MMSE; Folstein, Folstein, & McHugh, 1975]), dependence in basic activities of daily living (BADL) or limited hand function prior to the stroke, other neurological, orthopedic or psychiatric conditions or epilepsy. This study was approved by the hospital and university ethics board and all participants provided written informed consent.

Materials

The participants' attendance in the intervention sessions and usability (ability of the participants to understand and actually play the different consoles/games with their weaker UE), demonstrated the feasibility of using VG for practicing UE movement.

The following tools were administered pre- and post- intervention:

The Fugl-Meyer Upper Extremity Motor Assessment (FMA; Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975) was used to assess the motoric ability of the weaker UE to perform active movements ranging from 0 (no active movements) to 60 points (full active movement). The validity and reliability of the FMA has been well established for people with stroke (Hsieh et al., 2009).

Jamar Dynamometer (Hamilton, Balnave, & Adams, 1994) was used to assess grip strength. The mean grip strength of three trials was recorded in kilograms for the weaker UE.

The Action Research Arm Test (ARAT; Carroll, 1965) is a reliable and valid measure for assessing the functional ability of the weaker UE of individuals with stroke (Hsieh et al., 2009). Scores range from 0 (a non-functional hand) to 57 points (a fully functional hand).

Daily-use of the UE was quantified by **Actical™ accelerometers (Mini Mitter Co.)** worn on both wrists over three consecutive weekdays. This triaxial waterproof accelerometer weighs only 17 grams and is as small as a wrist watch (28X27X10 mm). It is sensitive to 0.05-2.0 G-force, samples at 32 Hz, and then rectifies and integrates acceleration over 15-second epochs as activity counts. Aiming to quantify functional UE movements, we eliminated the UE swing movements during gait. Therefore participants wore a third hip accelerometer with a step count. Significant differences between the accelerometer activity counts of the paretic and non-paretic UE of individuals undergoing subacute rehabilitation and between individuals with stroke to healthy older adults, established its validity (Rand & Eng, 2012). In addition, daily Actical wrist activity counts was moderately correlated to brain activation during a grip task in individuals with stroke (Kokotilo, Eng, McKeown, & Boyd, 2010) and to hand dexterity in older adults (Rand & Eng, 2010). Lastly, daily-use of the weak UE quantified by wrist accelerometers was found to moderately correlate to self-report measures of arm activity (r=0.52-0.66) (Lang, Bland, Bailey, Schaefe, & Birkenmeier, 2013).

Intervention protocols

Both interventions aimed to provide participants with a multitude of opportunities to produce movements of their weaker UE while minimizing compensatory movements (e.g. trunk movements). The therapists provided handling and/or verbal guidance and modified the activity (VG or traditional) demands according to the Occupational Therapy Practice Guidelines for Individuals with Stroke (Sabari & Lieberman, 2008). All sessions were carried out individually by an occupational therapist.

VG intervention. One of the following VG consoles (games) were used to encourage UE movements while the participant was seated; The Nintendo Wii (http://www.nintendo.com/wii) (e.g. Bowling, Sword Play), PlayStation 2 EyeToy (http://us.playstation.com/ps2/accessories/eyetoy-usb-camera-ps2.html) (e.g. Bubble pop, Mr.Chef) and PlayStation 3 MOVE (http://us.playstation.com/ps3/playstation-move/) (e.g. Table tennis). The console was chosen based on the participant's UE motor ability. The Wii and PS3 MOVE both require the use and operation of a hand-held remote while the EyeToy does not. Using different VG consoles for different sessions permitted for more flexibility and interest.

Traditional intervention. One of three occupational therapists, who were not aware of the study objectives and worked in the rehabilitation ward, treated the participants' UE using eclectic traditional approaches (such as neurodevelopmental, motor learning or task-specific) (Langhorne, Bernhardt, & Kwakkel, 2011). Tasks were therapeutic (such as rolling a ball, transferring cubes) and functional (setting the table, sorting cards) and included therapeutic aids as well as functional objects. Prior to the study the three occupational therapists met with the researchers to ensure consistent treatment for the participants across therapists.

Procedure

Individuals were approached once they were admitted for stroke rehabilitation and an explanation about the study was provided. If they agreed to participate, they signed a consent form and the MMSE and MI were administered. When found eligible, the remaining assessments were carried out and the accelerometers were worn for 3 consecutive weekdays. The pre- and post-intervention assessments were carried out by an occupational therapist blind to the intervention allocation. Participants were allocated to receive individual occupational therapy treatment either by playing VG or by receiving traditional therapy using block randomization.

Both interventions included 3 1-hour sessions per week for one month (or until discharge). In subacute rehabilitation participants usually receive five occupational therapy sessions per week; during the study three of the five sessions were focused on improving the UE (either by VG or traditional intervention). The additional two weekly sessions were focused on other domains treated by occupational therapists such as cognition, ADL, leisure (but did not include UE training). Participants also received standard rehabilitation care which included physiotherapy and in some cases speech therapy. Post-intervention assessments were then administered and the accelerometers were worn for an additional 3 consecutive week days.

Data Analysis

Due to the small sample, nonparametric statistics was used. Descriptive statistics (median and inter-quartile range [IQR]) was used to describe the population and the UE variables. Pre-intervention differences between the groups were assessed using Mann Whitney U test for the continuous variables and Chi square tests for the qualitative variables. Pre versus post differences were assessed by Wilcoxon Signed Rank Test. The differences between the two types of interventions for the percent change [{(post-pre)/pre} *100] for the UE outcome measures were assessed by Mann Whitney U test.

Results

A total of 55 patients were admitted to stroke rehabilitation between September 2011 and April 2012. Of these, 23 adults were eligible and 21 of them agreed to be included in the study. Twenty participants completed the intervention (see Figure 1 for CONSORT flow diagram). Their ages ranged from 49-85 years and they all had sustained an ischemic stroke. No statistical significant differences in demographic or stroke information were found (see Table 1). Two participants in the traditional intervention had sustained a recurrent stroke yet had higher MI scores, indicating less UE impairment.

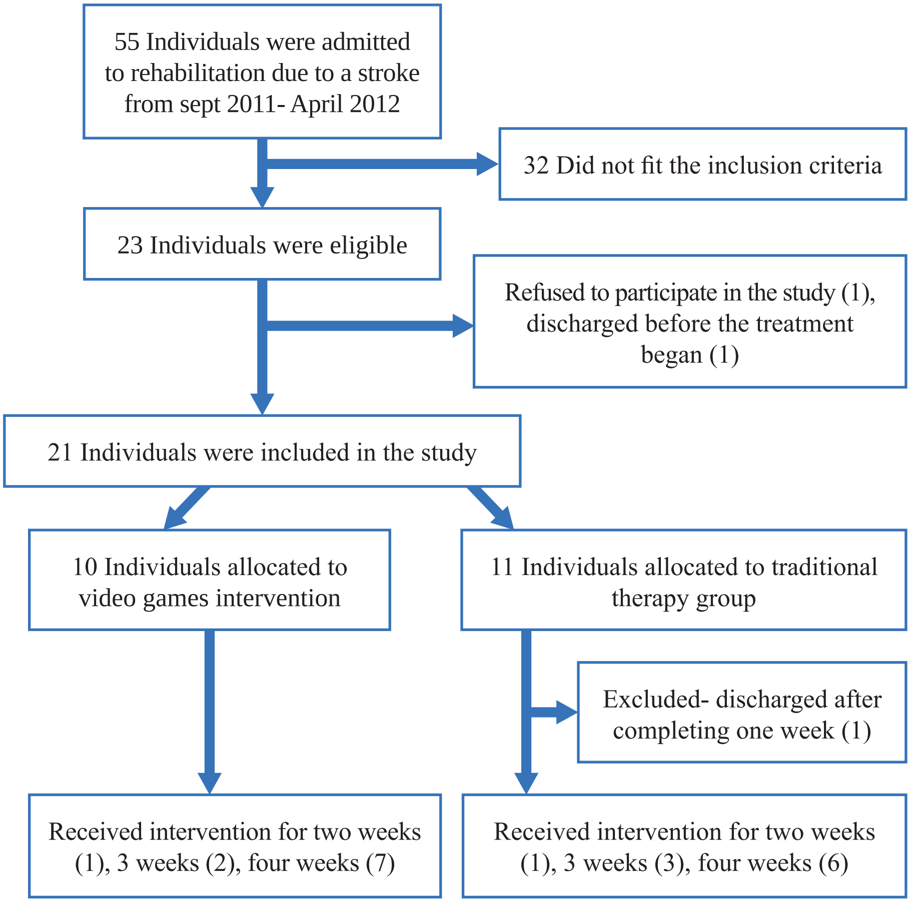

Figure 1. CONSORT flow diagram

Table 1

Characteristics of the Participants

	Video-games Intervention (N=10)	Traditional Intervention (N=10)	Mann-Whitney U Test
	Median (IQR)	Median (IQR)	z,p
Age	64.5 (59.5-68)	69.0 (64.7-81.2)	-1.5, 0.1
Days since stroke	18.0 (14.7-22.0)	22.5 (17.0-29.7)	-1.2, 0.2
Years of education	12.0 (9.2-12.0)	11.0 (8.0-16.0)	-0.1, 0.8
MMSE (0-30)	26.0 (25.0-29.0)	26.5 (19.7-28.0)	-0.7, 0.4
MI (0-100)	68.0 (59.7-77.0)	74.0 (53.5-79.0)	-0.3, 0.9
	N	**N**	**c^2, p**
First/recurrent stroke	10 / 0	8 / 2	2.2, 0.1
Side of CVA (Right/ left)	5 / 5	3/ 7	0.8, 0.3
Dominant affected (yes/no)	5 / 5	8 / 2	0.8, 0.3
Gender (M/F)	5 / 5	5 / 5	0.0, 0.6
Full/Partial independence in BADL prior to stroke	9 / 1	9 / 1	0.0, 0.7

Pre-intervention, no significant differences were detected for the weaker UE between two groups (FMA [z=0.47, p<0.05]; ARAT [z=0.49, p<0.05]; grip strength [z=0.8, p<0.05]; mean daily-use [z=0.10, p<0.05]). The weaker UE of all the participants ranged from mild to moderate motor impairment (FMA - 27-54 points/60 points), had a wide range of functional ability (ARAT - 11 – 57 points / 57 points) (see Table 2) and 9/10 participants had sufficient hand movement and could grasp the remote of the Wii or PS3 MOVE.

Table 2

The Median IQR Values of the Upper Extremity Pre- and Post –Intervention and Change

	Video-Games Intervention				Traditional Intervention				
	Pre-intervention	**Post-intervention**	**% Change**	**Wilcoxon z, p**	**Pre-intervention**	**Post-intervention**	**% Change**	**Wilcoxon z, p**	**Mann-Whitney U test z, p**
FMA	47.5 36.7-51.2	49.5 46.5-55.7	10.9 5.5-38.3	-2.5, 0.012	49.5 41.0-58.0	52.0 49.7-59.2	15.9 1.9-22.6	-1.99, 0.04	-0.3, 0.79
Grip strength kg	16.5 3.8-20.3	20.5 7.0-26.1	26.6 11.4-38.7	-2.8, 0.005	11.8 9.7-16.6	18.4 11.2-21.2	5.7 -4.6-84.1	-1.27, 0.20	-0.8, 0.4
ARAT	47.5 30.7-53.2	51.5 39.0-57.0	7.6 0.4-53.3	-2.2, 0.024	50.0 40.7-56.2	55.5 53.2-57.0	9.4 1.3-21.8	-2.25, 0.02	-0.4, 0.68
Mean daily use	46487 33822-92041	57131 37865-106810	16.6 -12.2-85.3	-1.6, 0.09	19389 10880-85225	32606 16068-61857	4.7 -36.2-91.4	-0.05, 0.95	-0.8, 0.43

FMA – Fugl-Meyer Motor Assessment 0-60; ARAT- Action Research Arm Test 0-57; Mean daily use – accelerometer activity counts; Wilcoxon – pre versus post differences; Mann-Whitney U test – differences in changes that occurred pre-post intervention between groups

Seven participants from the VG group and 6 participants from the traditional group received 4 weeks of intervention however, due to early discharge the remaining participants received intervention for only 2-3 weeks (see Figure 1 for details). Ninety-one percent of the eligible individuals (21 patients of 23) agreed to participate in the study when they were aware of the 50% chance of allocation into the VG intervention. Attendance was high with all 20 participants completing the study protocol. Participants with support from the occupational therapist were able to play the VG with their weaker UE.

The UE improved significantly for participants in both interventions in terms of motor and functional ability (See Table 2). Grip strength significantly improved only for the participants in the VG intervention and daily-use of the weaker UE, as measured by accelerometers, did not improve in either group.

Discussion

Using the weaker UE for playing VG in therapy facilitates repetitive purposeful movements in a challenging and fun way (Rand et al., 2014). Participants use their arm in a functional way to "touch", "move", "transfer" virtual objects within the VG, which is often difficult to achieve in the real world due to inadequate active movement. In this pilot randomized controlled trial, individuals undergoing subacute stroke rehabilitation received traditional occupational therapy or VG intervention aimed at improving the motor, functional ability and daily-use of their weaker UE. This comparison to traditional therapy, which enhances the internal validity of the study's findings, was the case in only three (Housman, Scott, & Reinkensmeyer, 2009; Pironet et al., 2009; Sucar, Leder, Hernandez, Sanchez, & Azcarate, 2009) of the 12 studies included in a recent meta-analysis (Laver et al., 2012) on the topic.

Although we hypothesized that the VG intervention would be more effective than the traditional therapy in improving the motor and functional ability of the weaker UE due to the unique attributes of this intervention (fun, motivating, repetitive, competitive), significant differences were not found. A larger and more homogeneous sample might lead to significant between-group differences.

Significant UE improvement of motor ability (10.9% [VG] and 15.9% [traditional]), and functional ability (7.6% [VG], 9.4% [traditional]) were found in the current study for the participants who received VG, as well as for the participants in the traditional group. Since both interventions were provided individually by experienced occupational therapists at the same intensity (3 sessions per week) and duration, it is not surprising. In both interventions, the movements and tasks were suited to the participant's motor ability and physical handling or (physical or verbal) guidance was provided by the therapist accordingly. The VG facilitated functional virtual tasks in a repetitive manner (such as reaching and touching virtual balloons/balls, reaching and eliminating warriors, reaching and dragging products at a fast-food restaurant), while the participants receiving traditional intervention practiced reaching, grasping and moving objects such as balls, cubes, or cups.

Interestingly, grip strength improved significantly only for the participants in the VG intervention (26% improvement) compared to the 5.7% improvement for the traditional group. While the Nintendo Wii and PS3 MOVE require sustained grasping of the remote for interacting with the game, the PS2 EyeToy does not require grasping at all. The traditional intervention includes training of grasping and releasing but not a sustained grasping of an object. Possibly, this factor enhanced the improvement in grip strength for the participants in the VG intervention and should be further researched.

Since both groups demonstrated significant improvement, when the UE improvement for all 20 participants was calculated, it was found to be in accordance to the expected improvement at the subacute stage [Mean (SD) FMA – 5.4 (6.1) points; Mean (SD) ARAT – 6.2 (9.4) points; and Mean (SD) grip strength – 3.8 (3.9)] and comparable with other studies (Harris & Eng, 2010; Rand & Eng, 2012).

This study is novel since the participants in the VG group received therapy for their UE solely by playing VG. Previous studies used VG as a supplement to standard rehabilitation care (Crosbie, Lennon, McGoldrick, McNeill, & McDonough, 2012; Neil et al., 2013; Peters et al., 2013; Yavuzer et al., 2008); which found it to be safe and to have the potential to improve the weaker UE. Our participants reportedly enjoyed the sessions and some of the participants had discussions regarding the highest game scores. Disappointment was also expressed by a few participants when the 4-week intervention ended. None of the participants asked to discontinue the VG intervention or to be transferred to the traditional intervention. These findings highlight the feasibility of solely using VG intervention for treating the weaker UE during subacute stroke rehabilitation. Future studies should also include satisfaction questionnaires or qualitative interviews to gain further insight of this experience for the participants at this stage.

The VG were used as a therapeutic tool to facilitate UE movements in an enjoyable manner. Using activity analysis of the VG games and consoles, the occupational therapist could choose to use one of the three consoles and games for the sessions based on the participant's UE movements and preferences, similar to their role in traditional therapy. Since the VG used in this study were not developed specifically for rehabilitation, some of the required movements might have been too difficult for the participants to perform. Moreover, some of the required movements within the games were very fast, thus not providing the participants or the therapist time to control or apprise the movements. Nevertheless, participants did not report pain or discomfort, which is in accordance with similar studies that used VG as a means of therapy. In addition, when playing VG the stimuli appear repeatedly on the screen, eliciting repetitive movements, which is one of the important factors for efficient motor recovery (Nudo, 2007). Some participants may get tired, but are not aware of this due to their engagement in the game. Fatigue was not assessed in this study but should be in the future.

In this study, the intervention provided was either traditional or VG therapy. It is possible that the combination of these therapies would result in even greater improvement. This was demonstrated in a recent study in which significant UE improvement was reported for 20 individuals with chronic stroke who received UE training using the Xbox Kinect (30 minutes) in addition to 30 minutes of conventional occupational therapy. However, since the 20 participants in the control group received only 30 minutes of conventional occupational therapy, it is unclear if the improvement was due to the Xbox or to greater total intervention time (Sin & Lee, 2013).

The motor and functional ability as assessed by UE clinical measures improved significantly, but the daily-use of the weaker UE as measured by wrist accelerometers did not change significantly, regardless of the type of intervention. A vast variance of daily-use was seen pre- and post-intervention for participants in both groups. Similar findings were reported for a cohort of 60 participants with subacute stroke (Rand & Eng, 2012). Following the intervention, daily use of the weaker UE of our participants was still much less (median [IQR] 57131 [37865-106810] daily activity counts in VG, 32606 [16068-61857] daily activity count in the traditional intervention) than the stronger UE of individuals with stroke (median 164,875 daily activity counts) and compared to the right (184,761) and left hands (159,698) of healthy participants (Rand & Eng, 2012). The fact that the improvement in the UE motor ability was not translated to actual use of the arm is disappointing but perhaps by combining VG with traditional therapy, it might facilitate the desired transfer to daily-use.

Study Limitations

Although the small and heterogeneous sample is the main limitation of this study, other studies assessing the effectiveness of VR included the same number or fewer participants (Saposnik & Levin, 2011).

Partial active movement of the weaker UE on admission to rehabilitation was one of the inclusion criteria, therefore these findings might not generalize to individuals with substantial weakness due to stroke. The dose and intensities of the movements during the sessions were not recorded. Longer and higher intensity interventions might lead to significant differences between groups, however this is difficult to implement at the subacute stage, since early supported discharge-programs are implemented in many countries (Fisher et al., 2011; Langhorne et al., 2011). Daily-arm use was quantified by accelerometers, however, we still do not know what types of movements were performed (active, passive, purposeful-eating, non-purposeful-flexing the elbow) and thus this was not taken into account in the analysis. Lastly, satisfaction from the interventions was not appraised in a standard manner.

Conclusions

This pilot study demonstrated that VG can be used as a tool for treating the UE at the subacute stage post-stroke, leading to improvement of the motor ability, functional ability and grip strength of the UE. Possibly, the combination of VG with traditional therapy in occupational therapy can facilitate the motor recovery and transfer of daily-use of the weaker UE of individuals recovering from stroke.

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