

# Continuation of balance training for stroke subjects in home environment using virtual reality

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## ABSTRACT

The objective of the telerehabilitation is a continuation of the rehabilitation process on subjects' home and making the therapists and physicians possible to follow the progress remotely. Hereby the pilot project with virtual reality based tasks for dynamic standing frame supported balance training is presented. Six stroke subjects participated in the preliminary study. The subjects performed the therapy five times a week, each time for up to 20 minutes for three weeks. The results were evaluated by objective game parameters as track time, number of collisions and clinical instruments Berg Balance Scale, Timed Up&Go and 10m walk test. The outcomes demonstrated a significant improvement of all parameters. However, the follow up after two weeks demonstrated that functional improvement could be possible on a long term, if the subjects continue with targeted tasks for extended period of time. Besides, the balance training could be continued on subject's home instead of the hospital, which would decrease the number of outpatients' visits and reduce related costs.

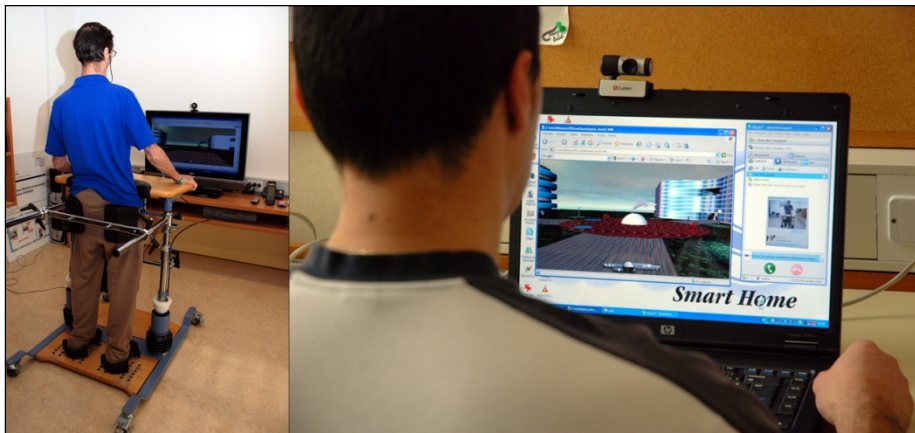
## 1. INTRODUCTION

One of the important issues in stroke population is balance control. The loss of balance in most cases results in fall and consequently in injuries. Therefore the restoration of static and dynamic balance is important for restoration of functional capabilities of stroke subjects. The outcome of research performed in the USA and UK in a group of stroke subjects demonstrated that functional capabilities may improve with rehabilitation in acute and chronic phase, when intensive therapy with repeatable and targeted tasks are applied (Kwakkel et al, 1999). The therapy in these conditions in clinical environment is assured by assistive devices that can assure safety. On the other hand these devices are ready for targeted tasks application in repeatable conditions. The person with severe stroke using assistive devices during hospital treatment require less physical effort of the medical staff, who can now focus on person and his/her task performance. The improvement of functional status can be achieved by applying target oriented tasks. Among such tasks is a simple ball catching or more complex task requiring person's attention and intervention in virtual reality (VR) environment (Holden, 2005). The task built up in VR enable a gradual increase of task's difficulty level, speed, sensitivity, specific goal and can be adopted to the subject's cognitive and motor capabilities (Cikajlo et al, 2009). VR supported therapy can improve balance capabilities in hemiparetic subjects with stroke when combined with conventional therapy (Kim et al, 2009) and on top of that when built up as computer games presents an additional motivation for subject (Rizzo et al, 2004).

But the main issue remains the limited time dedicated to the rehabilitation due to the financial limits of the health insurance system. It turns out that most of the subjects discontinue with any kind of activity that would enhance their functional capabilities when they are discharged from the rehabilitation hospital. Therefore it is important to give them an opportunity to continue with the motivating tasks they are familiar with. Nowadays the information-communication technologies (ICT) are ready to transfer video, audio, secure data and graphics in real-time and play a major role in telerehabilitation. The VR therapy can continue in remote rehabilitation center, local hospital or even on subject's home. This may lead to the shortening of inpatient hospital treatment and continuation of rehabilitation process (e.g. balance training) on subject's home. Besides, the telerehabilitation in combination with telediagnosics may decrease the number of required outpatient visits (Cikajlo et al, 2009).

Hereby we present a development of a VR supported balance training using the dynamic standing frame (Matjačić et al, 2000), which assures safety with limited range of motion and provide support during vertical

posture. The designed task in VR was used in target oriented balance training in the rehabilitation hospital in six subjects with stroke who also continued with the therapy all by themselves in the smart home. Only the physiotherapist supervised the therapeutic process occasionally via web browser and videoconference. In participating subjects also the clinical tests (Berg Balance Scale, Timed Up&Go and 10m walk test, standing on a single extremity) were carried out. We expected that the clinical tests would demonstrate rapid improvement of functional balance performance, which would not decline immediately after the therapy.



**Figure 1.** Balance training with task in virtual environment could be continued on subject's home (left). Therapist (right) supervised and advised the subject through the videoconference and followed the task performance in the Internet Explorer.

## 2. METHODOLOGY

### 2.1 Subjects

Six subjects with stroke (58.5 SD 12.1 years, 84.3 SD 11.5 kg, 176.3 SD 5.7 cm) participated in the VR therapy at the Institute's hospital and in the development of telerehabilitation based pro-longed therapy. The subjects with stroke were selected on the basis of the inclusion criteria:

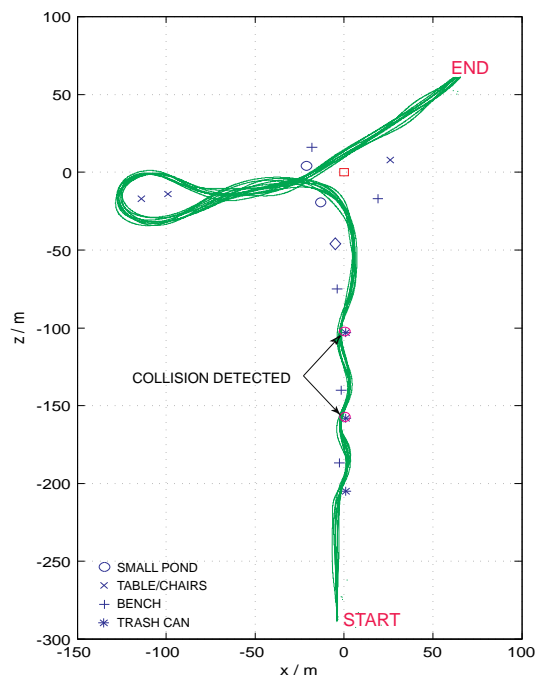
- show minimal ability to maintain upright posture and balance while standing in the standing frame,
- passed the cognitive test,
- checked cardiovascular status,
- subject has not taken any medications. Clinical examination was done by authorized medical personnel.
- subject had no prior experience with the dynamic balance and standing frame.

The methodology was approved by ethics committee of the University rehabilitation institute, republic of Slovenia and the subjects gave informed consent.

### 2.2 Equipment

In the last decade we have developed an assistive device for balance training in safe conditions, a dynamic standing frame, which was commercialized by a German company (Medica Medizintechnik, Germany) and is known as the BalanceTrainer (BT), a simplified passive device for balance training. The balance training standing frame (Figure 1. left) is made of steel base construction placed on four wheels, which when unlocked enable the apparatus mobility. The standing frame is made of aluminum and fixed to the base with passive controllable spring defining the stiffness of the two degrees of freedom (2 DOF) standing frame. The stiffness of the frame is set up according to the individual's requirements. On the top of the standing frame a wooden table with safety lock for holding the subject at the level of pelvis was mounted. The standing frame can tilt in sagittal and frontal plane for  $\pm 15^\circ$ .

The tilt of the frame was measured by commercially available three-axis tilt sensor (Xsens Technologies, Enschede, The Netherlands) and the action movement immediately resulted in the designated virtual environment. The virtual reality (modeled in VRML 2.0, running in MS Internet Explorer with blaxxun contact plug-in) based task required from the subject to "walk" by tilting the frame forward and "turn" by tilting the frame left or right. Figure 2 presents the path that was accomplished in several repetition of the VR task in one session (5 min.). The system also registered and counted the number of collisions with VR objects and measured the time that was needed to finish a single task (from START to END point).



**Figure 2.** Path accomplished during the VR supported therapy.

### 2.3 Protocol

The subject was standing in vertical position in the balance trainer with his hands placed on the wooden table in front of him and secured with safety lock from behind at the level of pelvis, enabling tilting forward, backward, left, right and all combination, but preventing to fall backward. The speed of “walk” or “turn” was proportional to the frame tilt angle. The subjects walked through the virtual environment on the path suggested by the therapist and were trying to avoid collision with the objects like can, bank, pool, tables, chairs, people... etc. At last they entered the building and the task started over and over again. During the activity the task time and number of collisions were detected and at the end presented to the subject. All the subjects needed additional assistance during balancing at the beginning of the task performance in rehabilitation hospital. After two weeks of the VR supported balance training they were set in the smart home environment and performed the task on their own. The tasks were designed to run in a web-explorer allowing the medical professionals to supervise (Figure 1. right), monitor and control the balance training process remotely through the World Wide Web. Besides, the videoconference enabled the physiotherapist to give the subject an important advice during the dynamic balance training, e.g. to correct the posture, hand placement, etc.

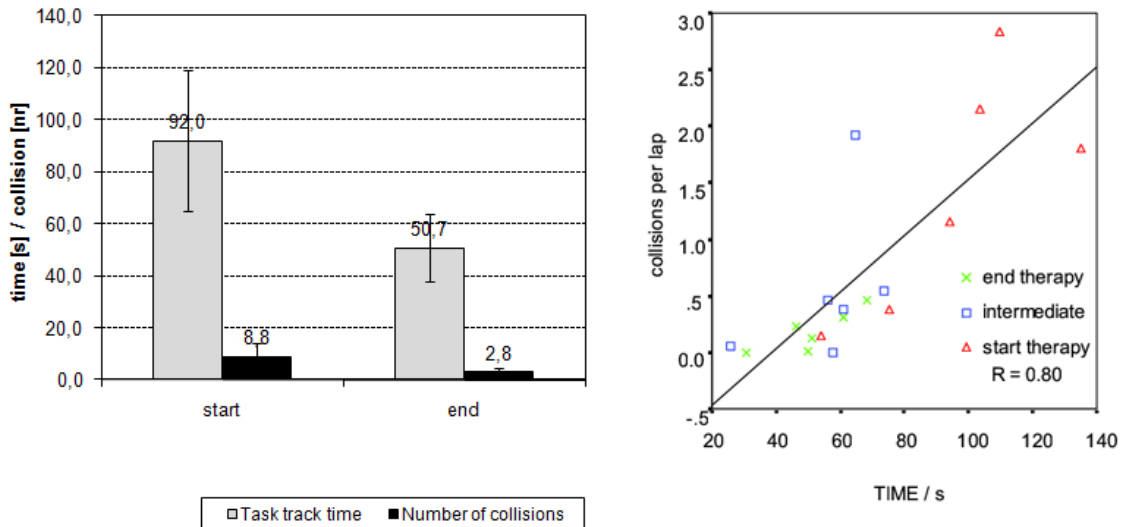
The subjects performed the therapy (VRBT – virtual reality balance training) five times a week, each time for up to 20 minutes for three weeks. The results were evaluated by objective game parameters as track time, number of hits and clinical instruments Berg Balance Scale, Timed Up&Go (TUG) and 10m.

**Table 1.** The protocol timetable.

clinical assessment	1. week	2. week	3. week	clinical assessment	4.-5. week	clinical assessment
	activity	activity	activity		no activity	
	VRBT	VRBT	VRBT		no BT	
	hospital	hospital	Smart home		-	

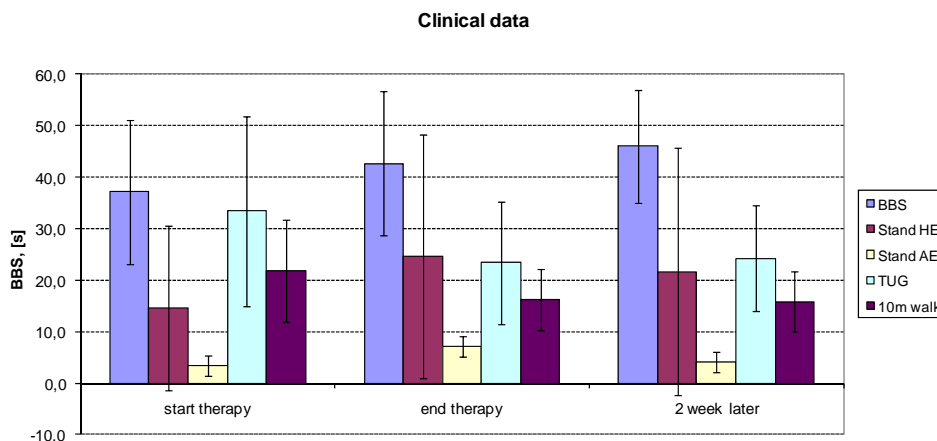
### 3. RESULTS

The task time was shorter for 42.7s (45%) and the subjects committed in average 6 (68%) collisions fewer (Figure 3). The collisions with objects were averaged on single VR task (“lap”) and a linear regression (Paerson’s coefficient) with VR task time demonstrated high level of agreement,  $R = 0.80$  (Figure 3). This confirmed our observations that subjects who managed to accomplish the task faster, also collided with fewer obstacles.



**Figure 3.** Measured outcomes. The subjects accomplished the VR task significantly faster with fewer collisions with objects after therapy. The “score” was also considered a motivation factor for each individual. Number of collisions normalized per task (lap) correlated well with the task time.

The Figure 4 shows clinical outcomes (10m test, TUG, BBS, standing on affected extremity - AE, standing on the healthy extremity - HE) of the participating subjects. The mean and standard deviation (SD) values for all subjects prior, after the training and the follow up are presented. All observed parameters have improved with training, although the assessment of the AE and also of the HE was not possible prior to the therapy for all subjects due to the impairment. Some subjects also used an additional walk aid or/and needed therapist’s assistance (a reason for higher SD). The BBS score improved from 37/56 to 42/56, standing on one leg was longer for HE up to 10s and AE up to 4s. The subjects also improved their TUG time in average for 10.0s and 10m walk time in average for 4.6s.



**Figure 4.** Clinical outcomes in subjects who participated in balance training with virtual reality tasks and the follow up after two weeks.

## 4. DISCUSSION

All participating subjects were able to accomplish the VR task faster at the end than at the beginning of the therapy and commit fewer collisions with obstacles. This can be attributed to the fact that the subjects mastered the exercise, as well as their balance abilities improved. The later is evident from fewer collisions which force the participating subject to transfer the load to the medial extremity and overcome the VR obstacle; otherwise the collision would be unavoidable. The improved balance abilities were evident from the BBS improvement and also from the fact that most of them could stand on the affected extremity, which was not possible for all subjects prior to the therapy. The gait clinical tests 10m walk and TUG also demonstrated significant improvement, which resulted in better overall mobility. Summarizing the outcomes we may claim that the functional balance status of the participating subjects has significantly improved. The outcomes obtained in the study were similar to the results of the study (Goljar et al, 2010) performed in two randomized group of subjects. The first group used only the same balance training device but without VR task, while the control group received conventional therapy only. Goljar et al did not find a significant difference between the two groups. However, the improvement of balance abilities was also comparable with the proposed VR balance training and the participating subjects' status remained the same after two weeks despite they had no balance training. Also we have not noticed any postural instability or VR sickness as a consequence of immersions in dynamic VR environment, thus we are aware of subjective physical experience of moving. The limitation in field of view may also have had impact on performance (Nyberg et al, 2006) as well as the problems in cognitive processing due to conversion of tilting into "walking". Also the VR supported learning may not be always transferrable to the real world applications or be effective immediately in the real world (Rose et al, 2000).

## 5. CONCLUSIONS

The telerehabilitation presents a novel approach in treatment of subjects with neuromuscular injuries or diseases (Lai et al, 2010). The proposed approach is not based only on teleconsulting which is indeed indispensable, but also supervises, controls and guides the therapy process remotely via internet. The clinical outcomes are comparable with conventional therapy and passive device supported balance training, but allows the patients more independence and earlier return home. Besides, the physiotherapists are relieved from strenuous manual work. The proposed approach also takes in consideration an economic view (Dhurjaty, 2004) since the number of outpatient visits could be reduced. Besides that the return home had positive effects on the motor performance of the subjects and one of the most important issues was that the subjects expressed personal satisfaction (Piron et al, 2008).

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