

# *Assessment of upper limb motor impairments in children with cerebral palsy using a rehabilitation robot and serious game exercise*

S. Dehem, G. Stoquart & T. Lejeune

Université catholique de Louvain

Institut de Recherche Clinique et Expérimentale, CARS

Cliniques universitaire Saint-Luc

Physical Medicine and Rehabilitation department

Belgium

stephanie.dehem@uclouvain.be,

thierry.lejeune@uclouvain.be

I. Brouwers

Cliniques universitaire Saint-Luc

Physical Medicine and Rehabilitation department

Belgium

V. Montedoro & M. Edwards

Université catholique de Louvain

Institute for Research in Psychological Science

Belgium

S. Heins, D. Galinski & B. Dehez

Université catholique de Louvain

Institute of Mechanics, Materials and Civil Engineering

Belgium

**Abstract**—Brain damaged patients require long and intensive rehabilitation. Recent advances in robotic devices and serious games provide two interesting innovations that together, intensify the therapy, and increase the patient motivation to engage in the therapy. In our project, we implemented a serious game on a rehabilitation robot in order to adapt the rehabilitation to the individual impairments of each patient. In the first phase of development, we assessed the patient impairments. Here, we report the validation and reproducibility of the robotic upper limb motor assessment. The protocol assessed four variables: passive range of motion, elbow flexor and extensor, isometric and isokinetic strength, and upper limb kinematics. The results showed that the protocol had good validity and reproducibility. In the second phase of development, the robotic motor assessment will be integrated to the serious game to provide a continuous measure of motor performance. This allow a continuous adaptation of the rehabilitation in function of each patient's impairments severity.

**Keywords**—upper limb; assessment; serious game; robotic; brain damaged

## I. BACKGROUND

Children with Cerebral Palsy (CP) have hemiplegia, diplegia or quadriplegia, which can sometimes be associated with abnormal sensitivity, upper limb tone, motor control and strength [1]. Rehabilitation robots allow for the application of different motor rehabilitation recommendations, including factors of treatment intensity, motor assistance (when needed), task oriented exercises, stimulating environments, and the integration of feedbacks [2]. A recent review highlights the potential for robotic therapy to improve upper limb function in children suffering from CP [3].

Despite the increased value of robots for rehabilitation, it remains a challenge to maintain the patient motivation during the long rehabilitation care. Each day, the patient must meet the same therapists, repeat the same movements, face the same difficulties and perceive small improvements. With serious games, it is now possible to insert exercises in a ludic and motivating environment [4], [5]. Serious games also allow to continuously adapt the rehabilitation difficulty according to the performances of the individual patient; a factor that can also be used to evaluate the rate of success of motor learning. If the exercise is too difficult, the patient will always fail, and he will not regain new motor skills. On the other hand, if the exercise is too easy, the patient will always succeed without regaining ability. Thus, it is essential that the exercise difficulty should be continuously adapted to the patient's ability [6].

Therefore, on the basis of this review, we can conclude that a combination of both technologies provides an encouraging possibility to improve patients' motor rehabilitation. Our project developed a serious game that can be adapted to patients' impairments, and be implemented on a rehabilitation robot. The first step of this project was to develop and validate a motor assessment protocol that will be integrated in a serious game.

## II. OBJECTIVE

The aim of the present study was to validate, establish norms, and to evaluate the reproducibility of the motor assessment protocol for upper limb impairments using a rehabilitation robot. The protocol was tested with healthy children and children with CP.

### III. METHODS

Forty-nine healthy children and twenty CP children aged between six and twelve years participated in this study. Each child was assessed clinically using standardized tests, and with the REAplan end-effector rehabilitation robot (Axinesis®) allowing upper limb mobilization in the horizontal plane [7]. Twelve healthy children were assessed twice to assess reproducibility.

The study was approved by the Saint-Luc ethics committee. Children participated freely to the study and both parents of each child provided written informed consent.

First, the patients' maximum passive range of motion was assessed with the robot by the therapist mobilising the upper limb fixed on the end-effector. Isometric elbow flexor and extensor muscle force was then assessed using the isometric dynamometer Microfet II, and with REAplan robot. For both isometric assessments patients were asked to develop their maximum force while their upper limb was fixed. Isokinetic flexor and extensor muscle force were also assessed with the REAplan robot. For these assessments, the end-effector mobilised the upper limb at 18 cm/s in three directions (in front of the patient, and at 45° diagonal on the left and right side), and the patients were asked to produce their maximum concentric force (force developed in the direction of the mobilisation). Finally, the upper limb kinematics were assessed using a pointing task to 30 targets evenly distributed in the REAplan working space.

### IV. RESULTS

The passive range of motion was moderately correlated to the upper limb length ( $r=0.66$ ;  $p<0.05$ ). The isometric forces assessed by the REAplan and the dynamometer were highly correlated for flexor muscles ( $r=0.8$ ;  $p<0.001$ ), and moderately correlated for extensor muscles ( $r=0.61$ ;  $p<0.001$ ). Results of isokinetic force assessment analysed with ANOVA showed that children developed a higher force when their upper limb was mobilized in a trajectory in front of them compared to trajectories angled 45° diagonal. This was true for both elbow flexor and extensor muscles ( $p<0.001$ ). For the kinematic assessment, the accuracy and the speed metric index were similar for all targets ( $p>0.05$ ). However, the averaged velocity and the straightness index showed a good correlation with the distance of the target (respectively  $r=0.77$ ;  $p<0.001$  and  $r=0.8$ ;  $p<0.001$ ). These indexes improved when the distance to reach a target increased. Finally, all assessments of healthy children showed very good reproducibility ( $ICC>0.82$ ;  $p<0.001$ ) and allowed to establish norms for each age group.

### V. DISCUSSION

The current study allowed the validation of upper limb passive range of motion and muscle strength assessment with

the REAplan robot. These assessments can now be integrated into a serious game in order to adapt and measure performance during the game. This allows for the game to be played within reachable areas, and the force level in the game to be adapted to the patients' force capability. The present study showed that patients developed a higher isokinetic force when their limb was mobilised in front of them, compared to 45 degree angles. This suggests that within the game, the patient could be asked to generate higher forces for target placed in front of them. The game may also require a greater straightness and velocity for the targets placed more distantly. Finally, norms were established for healthy children from six to twelve years allowing to compare individual CP children to expected levels of non-impaired performance.

### VI. CONCLUSION

The motor impairments assessment protocol developed in the present study can now be integrated into a serious game that continuously adapts the game to the patient's performance, and relative to norms performance.

### ACKNOWLEDGMENT

This work was supported by the Région Wallonne, the Fondation Saint-Luc and the Fondation Motrice. The authors would also like to thank Axinesis for the development of the rehabilitation robot, Martin Vanderwegen for his collaboration and finally all the subjects for their participation.

### REFERENCES

- [1] P. Eunson, "Aetiology and epidemiology of cerebral palsy", *Paediatr Child Health*, vol. 22, pp. 361-366, 2012.
- [2] T. Kitago, J. Krakauer, "Motor learning principles for neurorehabilitation", *Neurol Rehabil.*, vol. 110, pp. 93-103, 2013.
- [3] JY. P. Chen, A. M. Howard, "Effect of robotic therapy on upper-extremity function in children with cerebral palsy: a systematic review", *Dev Neurorehabil.*, vol. 19 (1), pp. 64-71, 2016.
- [4] N. A. Borghese, M. Pirovano, P. L. Lanzi, S. Wüest, E. D. de Bruin, "Computational Intelligence and Game Design for Effective At-Home Stroke Rehabilitation", *Games Health J*, vol. 2(2), pp. 81-8, 2013.
- [5] J. W. Burke, M. D. J. McNeill, D. K. Charles, P. J. Morrow, J. H. Crosbie, S. M. McDonough, "Optimising engagement for stroke rehabilitation using serious games", *Vis Comput.*, vol. 25(12), pp. 1085-99, 2009.
- [6] M. Da Silva Cameiro, S. Bermúdez I Badia, E. Duarte, P.F.M.J. Verschure, "Virtual reality based rehabilitation speeds up functional recovery of the upper extremities after stroke: A randomized controlled pilot study in the acute phase of stroke using the Rehabilitation Gaming System", *Restor Neurol Neurosci.*, vol. 29(5), pp. 287-98, 2011.
- [7] M. Gilliaux, A. Renders, D. Dispa, D. Holvoet, J. Sapin, B. Dehez, et al. "Upper Limb Robot-Assisted Therapy in Cerebral Palsy: A Single-Blind Randomized Controlled Trial", *Neurorehabil Neural Repair*, vol. 29(2), pp. 183-92; 2014.