



(SK) Kvantitatívne hodnotenie motorického pokroku pri terapii hornej končatiny pomocou systému PABLO: prípadová štúdia po CMP

(EN) Quantitative Evaluation of Motor Progress in Upper Limb Therapy Using the PABLO System: A Case Study Following Stroke

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SUMMARY/ABSTRACT

Starting point: Stroke is a leading cause of morbidity and mortality worldwide, often resulting in severe upper limb impairment. Robotic-assisted rehabilitation, such as the PABLO device, offers multimodal therapy by integrating biomechanical support, biofeedback, and interactive gaming.

Group: This case study examined two patients: a 72-year-old male with ischemic stroke and right-sided impairment and a 5-year-old boy with hemorrhagic stroke and left-sided impairment. The selection allowed assessment under different developmental and clinical conditions.

Methods: Patients underwent rehabilitation at the Specialized Treatment Institute Marína, Kováčová, including occupational therapy with PABLO. The assessment focused on upper limb range of motion (ROM), fine motor skills. Motor function was compared with the unaffected limb. Based on recorded measurements, the Fugl-Meyer Assessment for the Upper Extremity (FMA-UE) was used as a reference framework for functional interpretation.

Results: The pediatric patient demonstrated a 10° improvement in shoulder abduction, a 12° increase in wrist extension. The FMA-UE score was approximately 42 out of 66. The adult patient showed a 15° increase in shoulder flexion, 10° in wrist extension. The FMA-UE score was approximately 39 out of 66.

Conclusions: Based on the results of our case studies, we can conclude that the PABLO device is an objective evaluation and therapeutic tool. It enables the training of both motor and cognitive components. The restoration of upper limb function is crucial for improving patients' quality of life and their independence in daily activities. Patients perceive the integration of the device into therapy positively.

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KEYWORDS

Stroke, robotic-assisted rehabilitation, PABLO device.

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1 INTRODUCTION

A stroke is defined as a syndrome of acute focal neurological deficit attributed to vascular damage (infarction/ischemia) ¹. Stroke is the second leading cause of death or disability worldwide ². It can result from a wide range of pathological processes and risk factors, including hypertension, diabetes mellitus, atherosclerosis, and atrial fibrillation. The objective of this study is to analyze the effectiveness of therapy

using the PABLO device in post-stroke patients, assess its impact on motor function recovery, and evaluate its significance within comprehensive rehabilitation in a robotic rehabilitation system ^{3,4}.

Stroke

Stroke represents one of the most severe health impairments, predominantly affecting elderly individuals. However, in recent years, it has been increasingly diagnosed in younger individuals as well ⁵. Stroke occurs as a result of haemorrhage or ischemia, with cerebrovascular diseases in children being less common. Ischemic strokes are more frequent in neonates, primarily caused by congenital heart defects and other medical complications. In contrast, haemorrhagic strokes are more prevalent in adolescents and are often triggered by congenital vascular abnormalities leading to vessel wall rupture ⁶.

The clinical presentation of stroke is highly variable, depending on the location and extent of brain damage. In addition to motor impairments, patients may experience sensory deficits, visual field disturbances, symbolic function impairments, and psychological disorders. Stroke rehabilitation requires a comprehensive and individualized approach tailored to each patient ⁵. Physiotherapeutic methods play a crucial role in the rehabilitation process, with techniques such as the Vojta method, the Bobath concept, and proprioceptive neuromuscular facilitation being widely utilized. Occupational therapy is another essential component of rehabilitation, with these methodologies being applicable at various stages of stroke recovery based on the patient's current clinical condition ⁷.

In the acute stage of stroke, patients typically present with hypotonia, loss of active movement, and sensory disturbances. Therapy focuses on positioning and breathing exercises. During the subacute stage, spasticity develops, and rehabilitation efforts aim to reduce flexor spasticity in the upper limb and extensor spasticity in the lower limb. The patient gradually learns to stabilize posture in a seated and upright position, train balance, shift weight, and stabilize the knee joint with dorsiflexion of the ankle. When the patient is ready, gait training is initiated. This phase of rehabilitation facilitates recovery and gradual improvement in motor function. However, if significant motor deficits persist, the patient transitions into the chronic stage of stroke. This stage is characterized by pathological postural stereotypes, such as fixation of the upper limb to the chest, flexion contractures of the elbow and wrist, knee hyperextension, and circumduction gait of the paretic lower limb ⁸.

Early rehabilitation in post-stroke patients plays a critical role in restoring functional abilities and improving quality of life. Comprehensive therapeutic care includes physiotherapy, occupational therapy, speech therapy, and psychological support. Despite intensive rehabilitation, many patients continue to experience residual functional deficits that hinder daily activities. The primary factors influencing rehabilitation outcomes include the intensity of therapy, patient motivation, and overall health status ⁹.

Upper Limb in Stroke Patients

Damage to the sensory-motor cortex, subcortical brain structures, or cerebellum can lead to multiple pathological processes. The paretic upper limb loses movement fluency, and the patient is unable to perform voluntary movements. There is a reduction in hand activity, with a motor control shifting toward proximal segments, particularly the shoulder joint. Patients exhibit significant sensory deficits in the hand, manifested as impaired touch perception, proprioception, and object differentiation. Additionally, they experience difficulties with movement coordination, loss of grip function, and an inability to manipulate objects. The inability to combine complex movement patterns restricts fine motor skills and haptic object recognition.

Secondary changes occur in muscular, connective, and nervous tissues, leading to the development of spasticity, paresis, and dysfunction of sensory and motor nerves. One of the most common complications of stroke is shoulder joint subluxation accompanied by pain, significantly limiting upper limb function. These deficits severely impair the patient's ability to perform activities of daily living (ADL), negatively impacting their quality of life ¹⁰⁻¹².

The PABLO device, developed by Tyromotion, operates on advanced sensor technologies with dedicated software. The patient engages in therapy targeting impaired movements while receiving real-time visual feedback via the system. This therapy also stimulates cognitive functions through interactive games integrated into the software. The combination of motor training and cognitive stimulation promotes neuroplasticity, enhancing rehabilitation effectiveness.

All activities are conducted in the form of game-based therapy, increasing the patient's motivation to actively participate in exercises. The device includes a diagnostic mode that allows for the assessment of upper limb range of motion, and hand coordination. In clinical practice, PABLO is used for the rehabilitation of patients after stroke, traumatic brain injuries, and various neurological disorders. Beyond upper limb therapy and diagnostics, PABLO can be applied to lower limb rehabilitation, trunk stabilization, gait analysis, and ADL assessment. It is designed for patients of all age groups, from children to older adults

¹³.

2 GROUP AND METHODS

The study sample consisted of two individuals diagnosed with cerebrovascular accident (CVA) of different etiologies and lesion localizations: Patient 1: A 72-year-old male diagnosed with ischemic stroke affecting the right cerebral hemisphere, clinically manifesting as left-sided hemiparesis with significant impairment of upper limb (UL) function, fine motor deficits, and reduced sensory responsiveness. Patient 2: A 5-year-old boy with hemorrhagic stroke involving the left hemisphere, presenting with right-sided hemiparesis characterized by pronounced spasticity in the upper limb and deficits in fine motor skills.

Both patients underwent a comprehensive rehabilitation program incorporating therapy with the robotic device PABLO, aimed at improving upper limb motor function, and promoting sensory integration. Measurement outcomes and therapeutic interventions were recorded and compared to objectively assess the effectiveness of rehabilitation.

A detailed medical history was obtained from the patients, along with basic demographic and clinical data (gender, age, diagnosis), followed by a clinical examination. The PABLO robotic rehabilitation system was used to quantify the range of motion of the upper limbs (shoulder joints, elbow joints, and wrists). These measurements were performed using the Hand sensor, and the recorded values were subsequently analyzed ¹³. Motor function was interpreted with reference to the Fugl-Meyer Assessment for the Upper Extremity (FMA-UE), enabling alignment with standardized clinical frameworks. A modified approach inspired by the Fugl-Meyer Assessment for Upper Extremity (FMA-UE) was used to evaluate upper limb motor function. The assessment included active range of motion in the shoulder (flexion, abduction) and wrist (extension), expressed in degrees. Functional abilities like grip type and quality were assessed with emphasis on precision - pinch grip, lateral grip, pincer grip and spherical grip what was evaluated through clinical observation and comparison with the unaffected limb. Although this method does not represent full FMA-UE administration, it enables approximate scoring within the 0-66-point scale and provides a relevant overview of functional recovery.

In our study, the range of active motion of the upper limb was assessed using the standardized SFTR method, which records movements in the sagittal, frontal, and transverse planes. Measurements were performed with a clinical goniometer for selected key movements: shoulder flexion and abduction, and wrist extension, which directly correspond to the most frequently utilized movement patterns during therapy on the PABLO device. These movements reflect the main functional components activated during task-specific exercises and games included in the intervention program. The values were recorded in degrees before and after the therapy to quantify changes in motor function of the affected limb.

The assessment included an evaluation of fine motor skills, comparing the paretic hand with the healthy hand, with particular attention given to the execution and quality of grasping ¹². The values obtained from the initial and final measurements (before and after therapy) were compared to assess the patient's progress.

The tasks were structured based on the principle of progression, beginning with simpler exercises and gradually increasing in complexity. The therapist could dynamically adjust the difficulty level of the tasks during therapy, depending on the patient's individual performance and ability to adapt to increasing demands ¹³.

During the therapy, we reached some of the study limitations. Patients with very severe paresis or severe cognitive disorders/aphasia (who would not be able to understand the instructions or interact with the device) are often excluded. This limits findings only to mildly affected patients. A small sample can reduce

the statistical power of study and make it difficult to detect real (and clinically relevant) differences. Patients after CMP differ in the extent of damage (slightly to severe), localization of the lesion, the presence of cognitive deficits, spasticity and duration from CMP (acute, subacute, chronic phase). The inclusion of too wide or too specific groups may limit the applicability of findings to the entire population. Since patients have undergone comprehensive treatment in baths, respectively. Robotic Pablo therapy added to standard therapy, it is difficult to determine exactly what part of the improvement can only be attributed to Pablo and what other treatment. Tracking time after intervention is too short (28 days) and study cannot assess long-term sustainability or persistence of improvement. It is more difficult for a child's patient to undergo measurement and therapy and more intensive assistance of the therapist is needed and the results may be affected.

3 STARTING POINT, OBJECTIVE, TASKS

The objective was to determine the effectiveness of using the PABLO robotic device for the paretic upper limb in patients with hemiparesis. We hypothesized that in patients with a hemiparetic limb, the range of mobility in all joints of the upper limb will increase. However, rehabilitation with Pablo is one of the many other rehabilitation trainings that patients undergo during the spa treatment and hypothesized that Pablo has a significant effect to achieve better mobility of the upper limbs. We also hypothesized that your hand grips will improve in patients, both fine grip.

4 RESULTS

The Fugl-Meyer Assessment for the Upper Extremity (FMA-UE) was used as a reference framework for interpreting upper limb motor function. The pediatric patient corresponded to 42/66 points and the adult patient to 39/66 points. These results support the observed improvements in shoulder mobility, grip function, and motor coordination.

Pediatric patient: 5-year-old boy, hemorrhagic stroke, left-sided hemiparesis.

Table 1: Range of Motion in the Pediatric Patient – Left and Right Upper Limb (SFTR Notation)

Joint	SFTR Notation	Initial State LUL (°)	Final State LUL (°)	Improvement LUL (°)	Initial State RUL (°)	Final State RUL (°)	Improvement RUL (°)
Shoulder	(S)	40 - 0 - 160	40 - 0 - 170	+10	40 - 0 - 180	40 - 0 - 180	0
	(F)	160 - 0 - 30	170 - 0 - 30	+10	180 - 0 - 0	170 - 0 - 30	-10 / +30
Elbow	(S)	0 - 0 - 140	0 - 0 - 140	0	0 - 0 - 140	0 - 0 - 140	0
	(R)	80 - 0 - 60	85 - 0 - 70	+5	90 - 0 - 90	90 - 0 - 90	0
Wrist	(S)	30 - 0 - 20	30 - 0 - 20	0	30 - 0 - 20	30 - 0 - 20	0
	(F)	5 - 0 - 10	8 - 0 - 14	+3	20 - 0 - 25	20 - 0 - 25	0

Legend: LUL – Left Upper Limb, RUL – Right Upper Limb.

The table illustrates the range of motion values of individual upper limb segments in degrees (°) during the initial and final assessment. Differences in the measured values allow for an objective evaluation of therapy effectiveness. Based on the conducted measurements, it can be concluded that the rehabilitation intervention utilizing the PABLO robotic system had a positive impact on upper limb mobility. The results indicate an improvement in range of motion across multiple upper limb segments, with the most significant changes observed in the shoulder joint (flexion and abduction), elbow (supination), and wrist (ulnar and radial deviation). These improvements suggest the effectiveness of targeted physiotherapy with robotic assistance, supporting the concept of neuroplasticity and the adaptation of motor functions following neurological injury.

Table 2: Hand Grasps – Pediatric Patient

Type of Grasp	Initial Parameters LUL	Final Parameters LUL	Initial Parameters RUL	Final Parameters RUL
Pincer Grasp	1	3	2	2
Lateral Grasp	3	2	2	2
Spherical Grasp	2	2	2	2
Pinch Grasp	3	3	2	2

Legend: 1 – Grasp absent (patient is unable to perform the grasp). 2 – Grasp present (patient can perform the grasp correctly and functionally). 3 – Uncoordinated grasp (patient performs the grasp with difficulty, showing clumsiness or compensatory movements).

Table 3: Fugl-Meyer Assessment for the Upper Extremity (FMA-UE)

Patient	FMA-UE Maximum Score	Estimated Score	Interpretation
Pediatric Patient	66	42	Moderate impairment with significant improvements in joint movement and grasp

The FMA-UE scores are approximate estimates based on clinical observation and recorded motor performance parameters (ROM, grip function, coordination).

The findings indicate an improvement in fine motor skills, particularly in the pincer and lateral grasp of the paretic left hand. Following rehabilitation with the PABLO system, there was a significant enhancement in the pincer grasp (1 → 3) and lateral grasp (3 → 2), suggesting increased grasp functionality. These improvements confirm the effectiveness of targeted robotic-assisted therapy in enhancing manual dexterity and motor coordination in pediatric post-stroke rehabilitation.

Table 4: Range of Motion – Adult Patient (SFTR Recording)

Joint	SFTR Recording	Initial State RUL (°)	Final State RUL (°)	Improvement RUL (°)	Initial State LUL (°)	Final State LUL (°)	Improvement LUL (°)
Shoulder	(S)	10 – 0 – 140	15 – 0 – 150	+10	20 – 0 – 180	20 – 0 – 180	0
	(F)	110 – 0 – 15	122 – 0 – 15	+12	180 – 0 – 15	180 – 0 – 15	0
Elbow	(S)	0 – 0 – 140	0 – 0 – 140	0	0 – 0 – 140	0 – 0 – 140	0
	(R)	80 – 0 – 80	80 – 0 – 80	0	90 – 0 – 80	90 – 0 – 80	0
Wrist	(S)	80 – 0 – 80	80 – 0 – 80	0	90 – 0 – 80	90 – 0 – 80	0
	(F)	10 – 0 – 10	10 – 0 – 10	0	20 – 0 – 20	20 – 0 – 20	0

Legend: LUL – Left Upper Limb, RUL – Right Upper Limb.

The data suggest an improvement in the range of motion in the shoulder joint, particularly in flexion and abduction of the right upper limb (RUL). Other parameters remained largely unchanged, which may be attributed to individual patient limitations. Overall, the findings confirm a positive effect of robotic-assisted rehabilitation with the PABLO system on the mobility of the affected limb, reinforcing its potential for functional recovery in post-stroke patients.

Table 5: Hand Grip Function – Adult Patient

Grip Type	Initial RUL Values	Final RUL Values	Initial LUL Values	Final LUL Values
Pincer Grip	2	2	2	2

Lateral Grip	2	2	2	2
Spherical Grip	2	2	2	2
Pinch Grip	3	2	2	2

Legend: LUL – Left Upper Limb, RUL – Right Upper Limb. 1 – Grip absent (patient is unable to perform the grip). 2 – Grip present (patient is able to execute the grip correctly and functionally). 3 – Uncoordinated grip (patient performs the grip with difficulty, noticeable clumsiness, or compensatory movements).

Table 6: Fugl-Meyer Assessment for the Upper Extremity (FMA-UE)

<u>Patient</u>	<u>FMA-UE Maximum Score</u>	<u>Estimated Score</u>	<u>Interpretation</u>
<u>Adult Patient</u>	<u>66</u>	<u>39</u>	<u>Moderate-to-severe impairment; functional recovery observed post-therapy</u>

The FMA-UE scores are approximate estimates based on clinical observation and recorded motor performance parameters (ROM, grip function, coordination).

Results Interpretation

The results indicate that hand function remained stable all grip types in the adult patient. Notably, the pinch grip improved from an uncoordinated execution to a fully functional one, highlighting the positive impact of therapy on fine motor control.

A comparison of range of motion outcomes between the paediatric and adult patients reveals differences in the degree of improvement across upper limb segments. The most significant improvement in the pediatric patient was observed in shoulder abduction (F) on the affected left upper limb, increasing from 160° - 0° - 30° to 170° - 0° - 30° (+10°). In contrast, the adult patient demonstrated improvements in shoulder flexion (S) on the paretic limb, increasing from 10° - 0° - 140° to 15° - 0° - 150° (+10°), and in shoulder abduction (F) from 110° - 0° - 15° to 122° - 0° - 15° (+12°).

Less improvement was noted in the elbow and wrist joints. The pediatric patient demonstrated increased supination (R) in the paretic arm from 80° - 0° - 60° to 85° - 0° - 70° (+5°), whereas the elbow and wrist joint parameters in the adult patient remained largely unchanged.

Overall, the pediatric patient exhibited greater improvements in both shoulder and elbow range of motion compared to the adult patient. This suggests a higher efficacy of rehabilitation therapy in the younger patient, likely due to greater adaptability and neuroplasticity.

A comparison of grip function between the pediatric and adult patients highlights differences in rehabilitation outcomes. The pediatric patient showed improvements in pincer grip from 1 (unable to perform) to 3 (performs with difficulty) and in lateral grip from 3 (performs with difficulty) to 2 (performs functionally). In contrast, the adult patient maintained stable values at 2 (functional performance) for pincer, lateral, and spherical grips, with an improvement in pinch grip from 3 (performs with difficulty) to 2 (performs functionally).

In addition, the Fugl-Meyer Assessment for the Upper Extremity (FMA-UE) was used as a reference framework. The pediatric patient scored approximately 42 out of 66 points, while the adult patient scored 39 out of 66 points. These values further support the observed improvements in shoulder mobility and coordination.

In conclusion, the pediatric patient demonstrated greater progress in grip patterns compared to the adult patient, which may be attributed to the higher regenerative capacity of the nervous system in children.

5 DISCUSSION

Stroke (Cerebrovascular Accident - CVA) remains one of the leading causes of mortality and disability worldwide, with upper limb motor dysfunction and impaired coordination being among the most common consequences. Various therapeutic approaches exist for rehabilitating the paretic upper limb, one of which is robot-assisted therapy.

The use of the Fugl-Meyer Assessment (FMA-UE) as a reference framework confirmed functional progress in both cases. Motor outcomes aligned with 42/66 and 39/66 points respectively, allowing interpretation within the context of a standardized scale.

Pavan et al.¹⁴ conducted a study on 81 patients in the subacute stage of stroke, evaluating the effectiveness of neurorehabilitation using robotic devices, including the PABLO system. Their results demonstrated improvements in mobility, muscle strength, and the ability to perform activities of daily living (ADL). Although our patient sample was smaller and had different inclusion criteria, significant improvements in the evaluated parameters were also observed.

Kuo et al.¹⁵ compared the effects of robot-assisted therapy with the PABLO device to traditional rehabilitation in stroke patients. After 18 therapy sessions, they concluded that while both groups showed motor function improvements, patients undergoing PABLO-assisted rehabilitation exhibited higher motivation and satisfaction. In our study, subjective therapy assessment revealed that both patients responded positively to the integration of VR into their rehabilitation, with the pediatric patient showing greater enjoyment.

Susanto et al.¹⁶ investigated the effects of robot-assisted hand and finger training in stroke patients. Their study found that robotic rehabilitation was particularly effective in restoring proximal joint function, while hand and finger function remained more challenging to improve. Our results demonstrated improvements in grip function in both patients. The adult patient (72 years old) initially exhibited an uncoordinated pinch grip, which significantly improved by the end of therapy. The pediatric patient (5 years old) showed improvements in pincer and lateral grip.

Ranzani et al.¹⁷ compared the efficacy of robot-assisted therapy with traditional neurocognitive rehabilitation. Their findings indicated that robotic rehabilitation was not inferior to conventional methods, with comparable motor improvements. In our study, patients underwent a combination of standard rehabilitation and PABLO-assisted therapy within occupational therapy, achieving a comprehensive therapeutic effect. The results showed an increase in the range of motion, particularly in the shoulder joint of the adult patient, while the pediatric patient experienced notable improvements in forearm supination.

Lambercy et al.¹⁸ examined the effects of robot-assisted therapy on pronation and supination movements in stroke patients, evaluating them through the Fugl-Meyer Motor Assessment (FM) and Motricity Index (MI). Their findings demonstrated improvements in both motor function and grip strength following therapy. In our study, improvements in supination and pronation were observed only in the pediatric patient. However, significant overall improvements in range of motion were documented in both patients.

Aprile et al.¹⁹ analyzed the impact of robotic rehabilitation on cognitive function in stroke patients. Their results suggest that this therapy supports not only motor function recovery but also cognitive function enhancement, social engagement, and ADL performance. While our study did not directly assess cognitive function, the PABLO software included cognitive training elements that may have contributed to the overall patient improvements.

A similar approach to the use of robotic assistance in post-stroke rehabilitation was described in the study by Potašová et al.²⁰, which investigated the effectiveness of robot-assisted gait re-education using the Lokomat system. Although this study focused on the lower limbs, it identified comparable challenges to those encountered in our intervention using the PABLO device. In both cases, robotic systems incorporating biofeedback were integrated as part of standard neurorehabilitation. The Lokomat study did not find a statistically significant difference compared

to conventional therapy in restoring gait symmetry, highlighting—similarly to our case—the need for prolonged or combined therapy, personalized approaches, and increased frequency of interventions. This parallel supports the premise that robotic systems may enhance motivation and provide objective therapy monitoring; however, their effectiveness depends on multiple factors, including the duration of intervention and the rehabilitation phase.

In addition to motor changes, the rehabilitation process in post-stroke patients may also influence higher cognitive and linguistic functions. As noted by Marková et al.²¹, patients after stroke may benefit from targeted stimulation of higher linguistic functions, which supports neural pathway reorganization. The interactive tasks and visuomotor training within the PABLO system may therefore indirectly contribute to the stimulation of cognitive processes involved in motor learning.

According to Klobucká et al.²², the use of robotic rehabilitation in patients after CMP and its positive effect cannot be fully confirmed with comparison with standard therapies, but they also state that patients from robotically designed training clearly benefit. They also state that one of the most important factors to improve the patient's condition after CMP has the intensity of training. Our patients sample has undergone a combination of standard therapy and robotic therapy, and I cannot determine exactly how much robotic therapy has an impact on the patient's condition.

Hoidekrová et al.²³ evaluated robotically assisted therapy for locomotion with the involvement of the upper limbs and cognitive functions. Patients have been shown to improve in all areas. Within the assessed upper limbs, the patient showed 21 activities before therapy and after therapy of 27 activities out of a total of 29 activities evaluated. Another evaluation system has been used in therapy to show them an improvement. There was a significant improvement in therapy. In our sample, improved mobility and fine motor skills, which benefits the patient's self-sufficiency and ADL.

According to Aderinto²⁴, VR-based rehabilitation offers an effective method for CMP rehabilitation. Its main advantages include the ability to replicate scenarios that are experienced by patients on a daily basis, mainly common activities and thus the patient can practice these activities regularly. The nature of this method motivates patients to better results. However, its main shortcomings include the high cost of procurement. Furthermore, Amin²⁵ evaluated the efficiency of VR games with feedback. Patients after stroke showed increased dexterity, improved range of movement, strength of hands and grip. The outcome of this research confirms the idea that fully imerical VR-based rehabilitation games offer an effective platform for improving hands motor skills in rehabilitation after a stroke. Compared to our research, VR method can offer small to the same improvement and, as other authors says (see section of this discussion), an important feature is not a method of rehabilitation, but its intensity.

An important aspect of our findings is that patient progress was not solely attributed to PABLO-assisted rehabilitation but to a combination of comprehensive therapy, including individualized physiotherapy and occupational therapy. This suggests that robot-assisted therapy is particularly effective as part of a multimodal rehabilitation program, as supported by previous studies^{15,17}.

Another key factor is patient age. The interpretation of motor improvement must be considered in the context of the evaluation method used. Furka et al.²⁶ emphasize that the assessment of rehabilitation outcomes requires selecting appropriate statistical or clinical interpretation frameworks to distinguish true functional gains from natural variability or compensatory patterns. This supports the need to contextualize the improvements observed in our case studies within a broader multimodal rehabilitation process, rather than attributing them solely to PABLO-assisted therapy. The pediatric patient exhibited faster adaptive motor changes, whereas

the adult patient required a longer rehabilitation period but still achieved significant improvements in grip and movement patterns. This difference may be related to neuroplasticity, which is greater in younger individuals ¹⁹.

Our findings confirm that incorporating robot-assisted rehabilitation with the PABLO device has a positive impact on upper limb motor function recovery. Improvements were observed in both adult and pediatric patients, with the adult patient demonstrating progress primarily in range of motion, while the pediatric patient showed the most notable changes in grip patterns and forearm supination. These results support the use of robot-assisted therapy as an effective adjunct to standard rehabilitation.

6 CONCLUSIONS

Virtual reality is currently an essential medical tool used for both diagnostic and therapeutic purposes. The PABLO device enables the implementation of both aspects, with its primary application in the rehabilitation of neurological patients, although it is also utilized in other medical conditions. Based on the results, it can be demonstrated that incorporating this device into therapy provides significant benefits, offering a modern, objective assessment of functional deficits in the upper limb and hand, as well as an effective therapeutic tool.

The results indicate that patients who underwent therapy with the PABLO system achieved improvements in the range of motion of individual upper limb segments, as well as in functional grip parameters. The pediatric patient exhibited notable improvements, particularly in shoulder abduction and elbow supination while the adult patient demonstrated an increased range of motion primarily in the shoulder joint. Functional grip analysis showed that both the pediatric and adult patients experienced enhanced fine motor skills, with a significant improvement in pinch grip.

The findings of this study highlight the effectiveness of robot-assisted therapy with the PABLO device as part of a comprehensive rehabilitation process. It is important to emphasize that the observed improvements were not solely the result of therapy with this device but also of the combined rehabilitation procedures undertaken at the Specialized Treatment Institute Marína, Kováčová. Therapy with the PABLO device was applied within occupational therapy and supplemented with individual physiotherapy, achieving a synergistic effect in the neurorehabilitation process. Patients responded positively to the inclusion of PABLO in their rehabilitation, with interactive games in the software interface enhancing their motivation and active participation in therapy.

7 ZUSAMMENFASSUNG (SUMMARY/ABSTRACT IN GERMAN LANGUAGE)

Ausgangspunkt: Schlaganfall ist eine der führenden Ursachen für Morbidität und Mortalität weltweit und führt häufig zu schweren Beeinträchtigungen der oberen Extremität. Die robotergestützte Rehabilitation, wie das Gerät PABLO, bietet eine multimodale Therapie durch die Integration von biomechanischer Unterstützung, Biofeedback und interaktiven Spielelementen.

Gruppe: Diese Fallstudie untersuchte zwei Patienten: einen 72-jährigen Mann mit ischämischen Schlaganfall und rechtsseitiger Beeinträchtigung sowie einen 5-jährigen Jungen mit hämorrhagischem Schlaganfall und linksseitiger Beeinträchtigung. Diese Auswahl ermöglichte die Bewertung unter verschiedenen entwicklungs- und klinischen Bedingungen.

Methoden: Die Patienten absolvierten eine Rehabilitation im Spezialisierten Behandlungsinstitut Marína, Kováčová, einschließlich Ergotherapie mit dem PABLO-System. Die Bewertung konzentrierte sich auf den Bewegungsumfang (ROM) der oberen Extremität und die Feinmotorik. Die motorische Funktion wurde mit der nicht betroffenen Extremität verglichen. Basierend auf

den aufgezeichneten Messwerten wurde die Fugl-Meyer-Assessment für die obere Extremität (FMA-UE) als Referenzrahmen für die funktionelle Interpretation verwendet.

Ergebnisse: Der pädiatrische Patient zeigte eine Verbesserung der Schulterabduktion um 10°, eine Zunahme der Handgelenksexension um 12°. Der FMA-UE-Wert betrug etwa 42 von 66 Punkten. Der erwachsene Patient zeigte eine Zunahme der Schulterflexion um 15°, eine Zunahme der Handgelenksexension um 10°. Der FMA-UE-Wert betrug etwa 39 von 66 Punkten.

Schlussfolgerungen: Basierend auf den Ergebnissen unserer Fallstudien kann geschlossen werden, dass das Gerät PABLO ein objektives Bewertungs- und Therapiewerkzeug darstellt. Es ermöglicht das Training sowohl motorischer als auch kognitiver Komponenten. Die Wiederherstellung der Funktion der oberen Extremität ist entscheidend für die Verbesserung der Lebensqualität der Patienten und deren Selbstständigkeit bei alltäglichen Aktivitäten. Die Patienten bewerteten die Integration des Geräts in die Therapie positiv.

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