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(SK) Význam robotickej rehabilitácie ruky u starších ľudí

(EN) The importance of robotic hand rehabilitation in older adults

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SUMMARY/ABSTRACT

Starting point: The ageing of the population is a global trend that has serious implications for individuals and the functioning of society as a whole. Areas that are significantly affected by ageing include fine motor skills, which are essential for carrying out everyday activities. The aim of this pilot research was to evaluate the effect of robotic hand therapy on grip strength of selected grip types and manipulative functions in the older adults.
Group: The sample consisted of 16 participants (5 males and 11 females, mean age 76.56 ± 6.97 years) briefly hospitalized at the Department of Geriatrics, University Hospital Olomouc. Three participants preferred the left hand and 13 the right hand.
Methods: The participants underwent a 14-day treatment using the Pablo® X2 robotic device. Manipulation function was evaluated at entry and exit using the standardized Czech Manipulation Function Test and grip strength using the Pablo® Handsensor.
Results: The results showed statistically significant improvement for the cylindrical, pincer, and all but one of the tweezer grips. Scores on several subtests of the Manipulative Function Test also improved.
Conclusions: The results suggest that robotic rehabilitation can be used as an effective adjunct to traditional therapeutic approaches aimed at improving grip strength and fine motor skills in older adults.

KEYWORDS
Hand robotic rehabilitation, manipulative function, older adults
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1 INTRODUCTION

The ageing of the population ageing is a global trend that has serious implications for individuals and the functioning of society as a whole. In the Czech Republic, people aged 65+ make up approximately 20.8% of the total population, which represents more than 2.2 million people. This share has more than doubled since 1990, and predictions show that by 2050 more than a third of the Czech population will be over 65 years old (Český statistický úřad, 2023). This demographic trend is mainly driven by increasing life expectancy and the declining birth rate, which is reflected in increased demands on health and social systems (OECD, 2019). As the share of older people increases, there is a concomitant rise in the prevalence of chronic conditions such as cardiovascular disease, diabetes mellitus, arthritis and osteoporosis, i.e. conditions that significantly affect the functional abilities of older people (World Health Organization, 2021). All of these changes affect the quality of life of older adults, and it is necessary to try to contribute in a beneficial way to maintaining and possibly even increasing the quality of life in terms of the physical, psychological, mental and economic impact on both the individual and society, by all means possible (Gaul Alacova et al., 2023). Among the areas that are significantly affected by aging are fine motor skills, which are essential for performing daily activities such as grasping objects, writing, dressing, and manipulating small objects. A decline in these skills often leads to a loss of self-sufficiency, increased dependence on caregivers and higher risk of social isolation (Hoogendam et al., 2014). Changes in fine motor skills result from a combination of physiological, neurological and sensory changes typical of the ageing process. There is a slowing of motor reactions, reduction in muscle strength and precision of movements, and deterioration in coordination (Holtrop et al., 2014). In addition, older adults often suffer from musculoskeletal disorders that further complicate their motor function.

Testing of manipulative functions is therefore essential to objectively assess the level of self-sufficiency of older people and helps to identify the need for rehabilitation interventions early on (Swinnen, Gooijers, 2015). The aim of this testing is to quantify the degree of preserved hand motor skills, to identify possible impairments in fine and gross motor skills, and to enable the determination of appropriate therapeutic strategies. The test results also provide information on the level of risk of functional dependence and the ability to predict future health complications (Chen et al., 2024; Swinnen, Gooijers, 2015). Various standardised tests are used to assess manipulative function; these focus on a specific manipulative activity (e.g. Box and Block Test, Purdue Pegboard Test, Nine-Hole Peg Test, Manipulative Function Test, etc.) or on parameters of motor function, such as range of motion (using a goniometer) or grip strength (using a dynamometer).

There are various possibilities for prevention and therapy of fine motor skills disorders at an older age. An active lifestyle and regular exercise play a key role. Although general physical activity indirectly benefits hand and finger function by maintaining muscle strength and coordination, there are also specific exercises for the hands and fingers that help maintain dexterity and strength, such as manual work, housework and gardening, graphomotor training, etc. (Vyskotova et al., 2021). There is also a link between cognitive function and fine motor skills. Activities that stimulate the brain can indirectly stimulate fine motor skills by maintaining cognitive processing speed and attention. Such activities include solving crosswords and puzzles, playing memory games and learning new skills, for which, e.g. the University of the Third Age may be very beneficial (Kopřivová, Grmela, 2015).

If fine motor disability has already occurred, there are several therapeutic approaches that can be beneficial. These approaches are often part of physiotherapy or occupational therapy interventions, which may include Activity of Daily Living (ADL) training (e.g. hands-on practice with buttoning, lacing, opening containers, etc.) or specific hand exercises aimed at improving strength, dexterity and coordination. Art therapy or music therapy may be appropriate. Furthermore, neurorehabilitation may include mirror therapy, sensorimotor stimulation, proprioceptive neuromuscular facilitation, and others (Krivosikova, 2011; Vyskotová et al., 2021). Robotic rehabilitation has also proven to be very beneficial (Daňková, Pastucha, 2018; Konečný et al., 2017).

Robotic rehabilitation of the upper extremity (UE) is an innovative approach in neurorehabilitation that uses advanced technology (e.g. Gloreha robotic system, Amadeo®, Armeo®Spring, PABLO®X2, etc.) to support motor recovery in patients with mobility impairments. This form of therapy focuses on the restoration of UE function after neurological damage such as stroke, traumatic brain injury, spinal cord injury or neurodegenerative diseases (Gassert, Dietz, 2018; Su et al., 2024). However, with advancing age, natural changes can also cause a loss of muscle strength and mobility, leading to a reduction in self-sufficiency. Therefore, robotic rehabilitation is becoming increasingly popular as an effective tool for slowing these changes in older adults (Ju et al., 2023). Robotic rehabilitation can contribute to reducing the length of hospitalisation, reducing the need for long-term care and improving patients' self-sufficiency, which is particularly important in the ageing population. Although the acquisition cost of robotic systems is higher, analyses show that the long-term return on investment is favourable (Shankar et al., 2024). Linking robotic rehabilitation with telemedicine approaches may also play an important role in the future, with remote monitoring and therapy support contributing to further reductions in transport and inpatient care costs (Rodríguez-de-Pablo et al., 2012).

2 GROUP AND METHODS

2.1 CHARACTERISTICS OF THE RESEARCH POPULATION

The experimental group included 20 subjects over 65 years of age, admitted to the geriatric ward of the University Hospital (FN) in Olomouc, who met the following **inclusion criteria**: age over 65 years, hospitalisation for at least two weeks, reason for hospitalisation primarily other than upper limb, sufficient cognitive abilities (Mini Mental State Examination - MMSE >24), sufficient visual acuity, adequate level of auditory perception, ability to sit independently, and willingness to participate in the research. The **exclusion criteria** were as follows: neurological disease, severe orthopaedic disease with direct impact on manual dexterity that was not a direct consequence of advanced age, congenital developmental defects of the upper limbs, and severe psychiatric disease. Four subjects had to be excluded from the ongoing research due to early discharge from the hospital. The final cohort consisted of 16 participants, 5 males and 11 females, mean age 76.56 (± 6.97) years. Three participants preferred the left hand and 13 the right hand.

2.2 TEST METHODS

The Pablo X2 robotic device and the Test of Manipulation Function (TMF) were used for evaluation. The **Pablo® X2** by Tyromotion is a modern therapy device for the rehabilitation of patients suffering from motoric dysfunctions; it is primarily used for rehabilitation purposes in patients with dysfunctional motion- and grasping control, grasping accuracy, coordination, body control and balance (Stargen EU, 2022). The system employs motion and force sensors to facilitate both unilateral and bilateral training. It connects to a computer via Bluetooth. Assessment and therapy were conducted using the Pablo® Handsensor to quantify grip strength and the Pablo® Motion Sensor to monitor wrist movement.

The **Test of Manipulation Function** is a standardised assessment of hand function in unimanual and bimanual tasks, using five wooden objects from the Ministav kit (Needle, Cube, House, Pyramid, and Mummy). The TMF includes 17 subtests involving the folding, unfolding, or lifting of wooden objects using the dominant hand, non-dominant hand, or both. Task completion time is recorded in seconds using a stopwatch. The test allows for comparison between the dominant and non-dominant hand, as well as against standardised TMF values (Vyskotová and Macháčková, 2013).

2.3 COURSE OF THE INITIAL AND EXIT EXAMINATION

As part of the initial assessment, grip strength and TMF subtests were administered. During testing, the participant was seated on a bed with feet flat on the floor. A laptop with the Pablo® Handsensor was positioned on a table in front of the participant to measure grip strength in a standardised sequence: cylindrical (Fig. 1a), pincer, key (Fig. 1b), interdigital (Fig. 1c), and pinch grip, each performed with both the dominant and non-dominant UE. The position of the UE was not standardised; participants selected a posture that enabled optimal grip execution and maximal force generation. This approach ensured that measurements reflected individual functional capacity within a self-selected comfortable position. Data were recorded on a standardised form.

The TMF was then administered. Each subtest included one practice trial followed by three test trials, except for those with a prominent cognitive component—assembling the Cube, House, and Mummy according to a model—for which no practice trial was provided. Results were recorded on a standardised form.

a b c

Figure 1 - Testing a) cylindrical grip, b) key grip, c) interdigital grip using the Pablo® Handsensor (Source: L. Pařízková)

The exit examination, conducted one day after the final (eighth) therapy session, was used to evaluate the effects of the intervention. Grip strength was reassessed and the TMF was repeated.

2.4 COURSE OF THERAPY

The individual therapies were performed a total of eight times over 14 days. One session using the Pablo® X2 robotic system took approximately 20–30 minutes. The therapy sessions used games from the 1D accuracy, 1D reaction, 2D motor and 2D cognition categories offered by the software of the device. The games provided patients with visual and auditory feedback. This assisted them in learning motor skills. As both dominant and non-dominant HK were tested, participants always played five left-handed and five right-handed games. One game lasted two minutes. Three games focused on grip strength using the Pablo® Handsensor controller and two games on wrist range of motion using the Pablo® Motion Sensor (see Fig. 2).

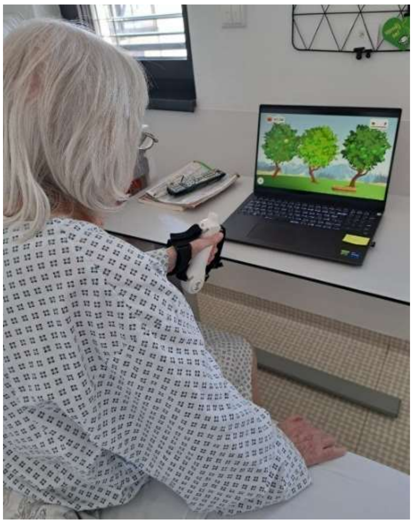

Figure 2 - Playing games with the Pablo® Handsensor (Source: L. Pařízková)

The selected games (Apple Picking, Firefighters, Balloon, Crossbow, Recycling, Farmyard, Labyrinth) were adapted to the current condition of the participants for the purpose of effective motor training. At the beginning of each game, a calibration was performed: the system measured the maximum range of motion of the trained area or the maxi-maximal force of the participant's handshake. The game automatically adapted to these maxima. It was also possible to adjust the load intensity (50%, 75%, 100%), which determined the maximum range of motion or handshake force that needed to be exerted to control the game correctly. The level of play and the direction of movement of the controlled object could also be adjusted. There were 10 levels of play, and the participant started at level 1 during the first session. The difficulty of each level was increased individually according to the participant's current condition. Once the patient managed the lower level, the level was increased by one.

2.5 STATISTICAL DATA PROCESSING

The data obtained from the measurements were entered into Microsoft Office Excel 2016 and then analysed using Statistica (version 13) software from TIBCO Software Inc. The measured data were characterised by basic statistical parameters (number of valid measurements, maximum, minimum, mean, standard deviation and difference). The normality of the data was verified using the Shapiro-Wilk test. Student's paired t-test was used to assess the statistical significance of data with normal distribution. For non-parametric data, the Wilcoxon paired test was used. Statistical significance was set at $p < 0.05$. The results are summarised in Table 1 and Table 2.

3 STARTING POINT, OBJECTIVE, TASKS

The effect of robotic rehabilitation on hand grip strength has already been investigated in many studies, which have repeatedly confirmed its positive effect (Bayındır et al., 2022; Daňková, Pastucha, 2018; Zhang et al., 2017). However, most of these studies focused primarily on overall grip strength and did not evaluate each grip type individually. In addition, these studies were often conducted on patients after stroke, whereas researche focusing on healthy older adults or on people with an involutional decline in hand function are considerably less frequent. Therefore, our aim was to evaluate the effect of robotic hand therapy using the Pablo® X2 device on fine motor skills on the older adults, focusing on grip strength in essential grip types. The standardised Czech Test of Manipulation Functions (TMF) was used to assess manipulative functions. The research was pre-approved by the Ethics Committee of the Faculty of Health Sciences of Palacky University in Olomouc (UPOL-153218/1030S-2024) and was conducted from August 2024 to April 2025 at the geriatric ward of the Olomouc University Hospital. Participation in the study was voluntary, and participants had the right to withdraw from the study at any time, even without stating a reason. Prior to the start of the measurement, all participants were thoroughly informed about the course, purpose and methodology of the study and subsequently signed the informed consent.

4 RESULTS

The results of the strength analysis for each grip type are presented in Table 1. Data were analysed using Student's paired t-test. A statistically significant increase in grip strength was observed in both the dominant and non-dominant hands following the therapeutic intervention for the cylinder grip, pinch grip, and most of the tweezer grips. For the remaining grip types, the observed differences did not reach the level of statistical significance.

Table 1 - Grip strength for different types of dominant and non-dominant grips

Grip type	Dominance/examination	Mean [N] / SD	Difference	p
Cylinder grip	Dominant / In	105.86 ±37.39	-5.12	0.0025**
	Dominant / Out	110.93 ± 38.17		
	Non-dominant / In	103.81 ± 39.04	- 4.22	0.0009**
	Non-dominant / Out	108.10 ± 39.65		
Tweezer grip I-II finger	Dominant / In	32.44 ± 11.94	-1.67	0.0137*
	Dominant / Out	34.11 ± 12.72		
	Non-dominant/ In	29.32 ± 8.77	-1.73	0.0056**
	Non-dominant / Out	31.05 ± 9.05		
Tweezer grip I-III finger	Dominant / In	29.78 ± 10.41	-1.81	0.0164*
	Dominant / Out	31.60 ± 11.40		
	Non-dominant / In	27.93 ± 7.46	-0.86	0.0324*
	Non-dominant / Out	28.79 ± 7.55		
Tweezer grip I-IV finger	Dominant / In	23.89 ± 8.13	-0.86	0.001**
	Dominant / Out	24.76 ± 8.66		
	Non-dominant / In	23.41 ± 7.19	-1.08	0.0035**
	Non-dominant / Out	24.50 ± 7.37		

Tweezer grip I-V finger	Dominant / In	15.91 ± 5.73	-0.39	0.0818
	Dominant / Out	16.30 ± 5.78		
	Non-dominant / In	17.00 ± 6.78	-0.65	0.0045**
	Non-dominant / Out	17.65 ± 6.70		
Key grip	Dominant / In	38.25 ± 13.10	-0.24	0.0819
	Dominant / Out	38.49 ± 13.34		
	Non-dominant / In	34.19 ± 11.23	-0.67	0.0531
	Non-dominant / Out	34.86 ±11.27		
Interdigital grip II-III finger	Dominant / In	22.06 ± 10.92	-0.06	0.8854
	Dominant / Out	22.13 ± 10.03		
	Non-dominant / In	18.01 ± 7.54	-0.30	0.1439
	Non-dominant / Out	18.31 ± 7.48		
Interdigital grip III-IV finger	Dominant / In	16.46 ± 8.53	-0.58	0.1339
	Dominant / Out	17.05 ± 8.25		
	Non-dominant / In	16.16 ± 8.16	-0.03	0.8397
	Non-dominant / Out	16.20 ± 7.90		
Interdigital grip IV-V finger	Dominant / In	14.65 ± 7.32	0.16	0.7105
	Dominant / Out	14.48 ± 7.37		
	Non-dominant / In	12.76 ± 6.63	-0.18	0.1698
	Non-dominant / Out	12.95 ± 6.83		
Pincer grip	Dominant / In	35.15 ± 10.15	- 1.36	0.0019**
	Dominant / Out	36.51 ± 10.13		
	Non-dominant / In	31.63 ±10.20	- 1.95	0.0009**
	Non-dominant / Out	33.58 ± 9.99		

Legend: N - Newton, SD - standard deviation, p – level of statistical significance, * p < 0.05, ** p < 0.01

The results of the manipulation function analysis are presented in Table 2. The Needle subtests were analysed using the Wilcoxon matched-pairs test. Although improvements were observed across all subtests, the changes over time did not reach the level of statistical significance. The remaining subtests were evaluated using Student's paired t-test. Statistically significant improvements were found only in the subtests within the House category as well as in those assessing cognitive functions in combination with manipulation (i.e. folding the Cube and House according to a given pattern).

Table 2 - Results of the Manipulation Function Test

Object	**Subtests/Examination**	**Mean [s] / SD**	**Difference**	**p**
Needle	BHS / In	12.46 ± 4.27	0.06	0.6251
	BHS / Out	12.40 ± 4.40		
	DHS / In	13.35 ± 4.63	0.08	0.4584
	DHS / Out	13.27 ± 4.62		
	NHS / In	14.29 ± 4.09	0.08	0.6652
	NHS / Out	14.21 ± 4.20		
Cube	BHA / In	2.97 ± 1.03	0.04	0.4497
	BHA / Out	2.93 ± 1.06		
	BHD / In	1.70 ± 0.53	0.05	0.1367
	BHD / Out	1.65 ± 0.50		
	DHA / In	2.82 ± 1.02	0.04	0.4461
	DHA / Out	2.78 ± 1.04		
	DHD / In	1.94 ± 0.52	0.01	0.8447
	DHD / Out	1.93 ± 0.59		
	NHA / In	2.87 ±1.09	0.04	0.0951
	NHA / Out	2.83 ± 1.07		
	NHD / In	2.43 ± 0.62	0.07	0.1053
	NHD / Out	2.36 ± 0.61		
	ACP / In	12.65 ± 4.20	0.30	0.0411*
	ACP / Out	12.35 ± 4.13		
House	LDHp / In	1.65 ± 0.55	0.10	0.0013**
	LDHp / Out	1.55 ± 0.58		
	LNHp / In	1.97 ± 0.72	0.06	0.0338*
	LNHp / Out	1.91 ± 0.71		
	LDHf / In	1.98 ± 0.77	0.11	0.0132*

	LDHf / Out	1.87 ± 0.74		
	LNHf / In	1.98 ± 0.71	0.14	0.0054**
	LNHf / Out	1.84 ± 0.67		
	AHP / In	18.70 ± 7.73	0.96	0.0012**
	AHP / Out	17.74 ± 7.50		
Pyramid	BHA / In	7.22 ± 2.10	-0.03	0.8739
	BHA / Out	7.25 ± 2.53		
	BHD / In	3.15 ± 1.11	0.12	0.0974
	BHD / Out	3.03 ± 1.12		
	DHA / In	6.32 ± 1.94	-0.03	0.7715
	DHA / Out	6.36 ± 2.06		
	DHD / In	3.63 ± 0.87	-0.01	0.9627
	DHD / Out	3.64 ± 0.94		
	NHA / In	7.07 ± 2.43	0.14	0.2376
	NHA / Out	6.92 ± 2.31		
	NHD / In	3.80 ± 1.19	0.03	0.4428
	NHD / Out	3.77 ± 1.27		
Mummy	DHA / In	15.59 ± 3.39	0.11	0.3619
	DHA / Out	15.48 ± 3.46		
	DHD / In	8.21 ± 2.08	0.05	0.5896
	DHD / Out	8.16 ± 1.93		
	NHA / In	15.93 ± 3.44	0.35	0.0564
	NHA / Out	15.58 ± 3.28		
	NHD / In	8.80 ± 2.25	0.02	0.8473
	NHD / Out	8.78 ± 2.39		
	AMP / In	27.59 ± 8.60	0.59	0.0696
	AMP / Out	27.00 ± 9.01		

Legend: SD - standard deviation, s - second, p - level of statistical significance, * $p < 0.05$, ** $p < 0.01$, BHS - Both hands sewing, DHS - Dominant hand sewing, NHS - Nondominant hand sewing, BHA - Both Hands Assembling, BHD - Both Hands Dismantling, DHA - Dominant Hand Assembling, DHD - Dominant Hand Dismantling, NHA - Nondominant Hand Assembling, NHD - Nondominant Hand Dismantling, ACP - Assembling the Cube according to Pattern, LDHp - Lifting the House by Dominant hand using a palm grip, LNHp Lifting the House by Nondominant hand using a palm grip , LDHf - Lifting the House by Dominant hand using a finger grip, LNHf - Lifting the House by Nondominant hand using a finger grip, AHP - Assembling the House according to Pattern, AMP - Assembling the Mummy according to Pattern

According to TMF standards, participants performed within the normative range for the 65+ age group, indicating that their manipulative abilities were preserved at a level consistent with age-related expectations.

5 DISCUSSION

Manipulative functions play a crucial role in the execution of activities of daily living, which are fundamental to maintaining independence in old age. However, aging is accompanied by complex changes in the neuromuscular and sensory systems, which can adversely affect these abilities (Seidler et al., 2010). The deterioration of manipulative functions in older adults impacts not only their self-sufficiency but also carries serious psychological and social consequences. It can limit participation in preferred leisure activities, reduce social interaction, and diminish overall life satisfaction. Maintaining these abilities supports an active lifestyle and contributes to improved quality of life (Hoogendam et al., 2014; Kopřivová & Grmela, 2015). Given these considerations, innovative rehabilitation approaches aimed at mitigating the effects of age-related changes and supporting the preservation of independence in older adults are becoming increasingly important. One promising approach is robotic rehabilitation, which employs specialised devices for the targeted training of motor functions. Research indicates that robot-assisted therapy can improve grip strength, motor coordination, and functional independence in older individuals (Lo et al., 2010; Mehrholz et al., 2018). The objective of this therapy is to deliver intensive, repetitive, and goal-oriented physical activity – key elements for promoting neuroplasticity (Gassert & Dietz, 2018). For older adults, whose natural regenerative capacity is limited, this process is particularly critical, as aging is associated with the loss of neural connections and cognitive decline, both of which negatively influence motor performance. Robotic devices offer precise movement guidance, individualised load adjustment, and real-time feedback, which is especially beneficial for individuals with reduced muscle strength or limited mobility (Ju et al., 2023).

Grip strength testing is recommended as a marker of healthy aging and a potential tool for clinical assessment (Čelko, Gúth, 2018). As grasping is a fundamental component and prerequisite of manipulation, understood as the interaction between the hand and the object being held (Bršhnová, 2002), our pilot study focused on measuring grip strength, a well-established predictor of overall functional status, morbidity, and mortality (Rantanen, 2003). We investigated the effects of therapeutic interventions using the Pablo® X2 robotic device on grip strength in older adults, assessing both the dominant and non-dominant hands. Following a two-week intervention, we observed a statistically significant improvement in the strength of the cylindrical and pinch grips, as well as in most tweezer grips. In contrast, no statistically significant changes were found for the key and interdigital grips.

The cylindrical grip is considered one of the fundamental functional grasp types commonly used in daily activities (Vergara et al., 2014). It involves the palm and all fingers and does not require fine coordination of individual finger movements. Moreover, this type of grip is associated with finger flexion, which was a primary focus of the Pablo® therapy. The results of our study demonstrated an improvement in cylindrical grip strength in both the dominant hand (increase of 5.12 N; $p = 0.0025$) and the non-dominant hand (increase of 4.22 N; $p = 0.0009$) following only two weeks of therapy using the Pablo® X2 robotic device. It is likely that the ability to perform this grip remains relatively well-preserved in older adults due to its frequent use in everyday tasks, which may contribute to the more favourable outcomes observed during therapy (Radder et al., 2019).

In the case of tweezer grips, the results indicated statistically significant improvements in most types. The greatest increase was observed in the grip between the thumb and index finger and between the thumb and middle finger on the dominant hand. These findings are consistent with the study by Vanoglio et al. (2017), who used the Gloreha robotic system in post-stroke patients and reported improvements in fine motor skills, particularly in the tweezer grip between the thumb and index finger, with an average increase of 1.5 N after three weeks of therapy. In comparison, the data obtained in our study revealed similar improvements for the dominant hand (1.67 N) and slightly higher values for the non-dominant hand (1.73 N).

An interesting finding was that the grip between the thumb and little finger did not show a statistically significant improvement on the dominant hand, while a significant increase was observed on the non-dominant hand. This difference may be partly explained by the lower baseline strength of the non-dominant limb, which may have allowed the therapy to produce a more pronounced effect. Since the grip between the thumb and little finger is rarely used in everyday life, it is possible that no significant improvement was achieved on the dominant hand. Furthermore, the initial grip strength on the dominant hand was slightly higher, which may have limited the extent of measurable change during the short treatment period, preventing it from reaching statistical significance.

Another grip type that showed significant improvement was the pinch grip. This grip is commonly used in everyday tasks such as buttoning clothing or manipulating small objects, requiring fine coordination between the thumb, index, and middle fingers. The motor coordination necessary to perform this grip is more demanding compared to the cylindrical grip (Li et al., 2022). The results of our study revealed a statistically significant increase in pinch grip strength on both hands, with an average gain of 1.36 N on the dominant hand and 1.95 N on the non-dominant hand. We suggest that, due to its frequent involvement in activities of daily living (ADLs), this grip may be more easily improved even at an older age. Repeated engagement in ADLs may promote the formation of new functional neural connections and facilitate adaptation to age-related changes (Dietz & Gassert, 2018). The improvement in pinch grip observed in our study aligns with findings by Vanoglio et al. (2017), who reported a positive effect of robotic therapy using the Gloreha system on fine hand motor skills, including increase in pinch and tweezer grip strength. Similarly, Bayindir et al. (2022) found that incorporating robot-assisted therapy into rehabilitation programs resulted in improved grip strength and manual dexterity.

While cylindrical, pinch, and most tweezer grips showed statistically significant improvements following the two-week robotic intervention, key and interdigital grips demonstrated only non-significant increases in strength. However, this does not imply that these grip types cannot benefit from focused training. From a biomechanical perspective, key and interdigital grips rely heavily on the activity of intrinsic hand muscles – particularly the interossei and lumbrical muscles responsible for precise finger abduction and adduction. In the key grip, the opponens pollicis muscle plays a crucial role, enabling thumb opposition to the index finger (Schreuders et al., 2007). These muscles are particularly susceptible to age-related atrophy, both in terms of muscle mass loss and a reduction in motor unit numbers (Deschenes, 2004). Functionally, the frequency with which a grip is used in daily life is also important. Cylindrical and pinch grips are commonly used in household tasks and account for more than 50% of all grips performed (Bullock et al., 2015), whereas the key grip has been observed in only 4.7% of manipulative actions (Vergara et al., 2014). These data suggest that key and interdigital grips are relatively infrequent in everyday life – for example, when holding a key or separating thin objects. The low frequency of these movement patterns in daily activities may contribute to their gradual weakening, consistent with the 'use it or lose it' principle. Motor functions that are not regularly activated tend to decline more rapidly with age and exhibit a reduced response to rehabilitative interventions (Kikkert et al., 2016).

The results of our study may also have been influenced by the way the Pablo® Handsensor was used during the therapy. This sensor primarily targets movements in the sagittal plane (flexion and extension of the fingers), which are characteristic of cylindrical, tweezer, and pinch grips. In contrast, key and interdigital grips require movements in the frontal plane (abduction and adduction), which were not sufficiently stimulated by this intervention. From a clinical perspective, however, it is important to emphasise that even relatively small improvements in grip strength achieved through therapy can represent the difference between independence and dependence in activities of daily living (ADLs) among older adults, thereby improving their quality of life (Bohannon, 2019).

In our study, we also investigated whether robot-assisted rehabilitation could improve manipulative function in older individuals. Participants performed within the normative range established for the 65+ age group according to TMF standards, indicating preserved manipulative abilities at a level appropriate for their age. This test involves combinations of grips used to manipulate five objects of basic geometric shapes. In this case, no significant changes were generally observed. Short-term training of simple movements using the Pablo® X2 did not result in an improvement in the manipulative skills of the participants. Nevertheless, significant improvements were observed in the 'House' subtests (which involve lifting with palmar and finger grips), as well as in TMF subtests incorporating both manipulative and cognitive components (e.g. folding the Cube and House according to a pattern). In this context, the palmar grip used for lifting the House was functionally similar to the cylindrical grip, while the finger grip resembled the pinch or a modified tweezer grip, as taxonomically classified by Feix et al. (2016). These grip types are commonly employed in daily life, as confirmed by studies mapping grip frequency throughout the day (Vergara et al., 2014). Both types predominantly involve the activation of finger flexor muscle groups, the strengthening of which was the primary target of the Pablo® X2 robotic therapy. Regular and structured practice of these movements may have contributed to a more secure grip, smoother manipulation, and faster task execution. These findings suggest that robotic therapy using the Pablo® X2 device may enhance not only grip strength, but also the speed and functional efficiency of grip performance.

An interesting finding was that the greatest improvement was observed during the lifting of the 'House' using a finger grip with the non-dominant hand. This may be attributed to the greater potential for improvement in the non-dominant hand, which typically exhibits lower baseline performance compared to the dominant hand (Levin et al., 2015). Robotic therapy appeared to compensate for deficits in coordination and precision of the non-dominant upper limb, resulting in a substantial enhancement of measured parameters.

Improvements in the cognitive-manipulative subtests may have been influenced by a more secure grip of the pieces, smoother upper limb movements, and more efficient problem-solving strategies during pattern assembly. The potential impact of task repetition should also be considered. Given that only two weeks elapsed between the initial and final assessments, participants may have retained some memory of the specific task sequence. This corresponds to theoretical principles of motor learning, which suggest that repeated task execution facilitates subsequent performance and contributes to the automation of motor sequences (Schmidt & Lee, 2019). This effect may have been more pronounced in complex tasks with a longer duration and cognitive component, where the short interval between assessments could have aided recall of previously successful strategies. In contrast, for simpler and faster manipulative tasks, participants may have reached their performance ceiling, limiting the potential for further improvement.

Additionally, the cognitive component of the therapeutic intervention itself may have contributed to overall improvements, as the therapeutic program included cognitive game tasks. These required precise targeting, object tracking, and spatial coordination, and, similar to other game-based interventions, were accompanied by immediate visual and auditory feedback. It is well established that multisensory feedback can significantly accelerate motor learning (Levin et al., 2015; Mlíka et al., 2023)

6 CONCLUSION

This was a pilot study and, as such, has certain limitations - most notably the small sample size short intervention time, the absence of the long-term effect, possible memory effect in repetitive testing and short intervention period. The given timeframe may not be sufficient to induce long-term changes, particularly in older individuals. The current research captures only the short-term impact of therapy; its long-term effectiveness remains unexamined.

Moreover, the practical applicability of these findings may be constrained by economic factors, such as the high acquisition cost of the Pablo® X2 device and its limited availability outside specialised centres. When planning to purchase robotic equipment, it is essential to consider the cost/benefit ratio (price of the device, operation, repairs, operator training vs. real benefits for the patient or savings in therapist labor). Purchase price and operating costs are a significant disadvantage of robotic rehabilitation (Klobucká et al., 2022).

The results of our pilot study suggest that even short-term training using robot-assisted rehabilitation can lead to improvements in grip strength and manipulative abilities in aging individuals. In this sample of participants admitted to a geriatric department, the potential for improvement was observed in the basic types of grip strength in both the dominant and non-dominant hands, which was subsequently reflected in performance on several subtests of manipulative function.

Although this study did not directly assess the ability to perform activities of daily living (ADLs), the observed improvements in fine motor skills may be considered a prerequisite for greater independence in everyday tasks. Enhanced manipulative function contributes to a better quality of life in older adults. Future research should explore the long-term effects of robotic rehabilitation and how such interventions might be integrated into routine clinical care. The findings of this study may also serve as a foundation for further investigation in this field.

7 ZUSAMMENFASSUNG

Die Alterung der Bevölkerung ist ein globaler Trend, der schwerwiegende Auswirkungen sowohl auf den Einzelnen als auch auf die Funktionsweise der Gesellschaft als Ganzes hat. Zu den Bereichen, die durch die Alterung erheblich beeinträchtigt werden, gehören die feinmotorischen Fähigkeiten, die für die Ausführung alltäglicher Aktivitäten nötig sind. Das Ziel dieser Pilotstudie war es, die Auswirkungen der robotergestützte Handtherapie auf die Griffstärke ausgewählter Griffarten und die manipulativen Funktionen bei älteren Menschen zu untersuchen.

Die Stichprobe umfasste 16 Participanten (5 Männer und 11 Frauen, das Durchschnittsalter von 76,56 ± 6,97 Jahren), die kurzzeitig in der Abteilung für Geriatrie des Universitätsklinikums Olomouc stationär behandelt wurden. 3 Participanten bevorzugten die linke Hand und 13 Participanten die rechte Hand.

Methoden: Die Participanten unterzogen sich einer 14-tägigen Behandlung mit dem Robotergerät Pablo® X2. Die manipulative Funktion wurde zu Beginn und am Ende der Behandlung mittels des standardisierten tschechischen Tests der manipulativen Funktionen ausgewertet. Für die Griffstärke wurde Pablo® Handsensor verwendet.

Ergebnisse: Die Ergebnisse zeigten eine statistisch signifikante Verbesserung bei Zylinder-, Zangen- und allen Pinzettengriffen außer einem. Auch die Ergebnisse in mehreren Untertests des Tests der manipulativen Funktionen verbesserten sich.

Schlussfolgerung: Die Ergebnisse deuten darauf hin, dass die robotergestützte Rehabilitation als wirksame Ergänzung zu den herkömmlichen therapeutischen Ansätzen zur Verbesserung der Griffkraft und der Feinmotorik bei älteren Menschen eingesetzt werden kann.

REFERENCES

Bayındır, O., et al. (2022). "The effect of adding robot-assisted hand rehabilitation to conventional rehabilitation program following stroke: A randomized-controlled study". *Turk J Phys Med Rehabil.* 68 (2). pp 254-261. doi:10.5606/tftrd.2022.8705. E-ISSN 2587-1250.

Bohannon, R. W. (2019). "Grip Strength: An Indispensable Biomarker for Older Adults". *Clin Interv Aging*. 14. pp 1681-1691. doi:10.2147/CIA.S194543. ISSN: 1178-1998.

Brůhnová, L. (2002). "Testování úchopu jako základ pro nácvik úchopových forem". *Rehabilitácia*. 35. pp.102-104. ISSN 0375-0922.

Bullock, I. M., et al. (2015). "The Yale human grasping dataset: Grasp, object, and task data in household and machine shop environments". *The International Journal of Robotics Research*. 34 (3). pp 251-255. doi:10.1177/0278364914555720. ISSN 0278-3649.

Čelko, J., Gúth, A. (2018). „Sila stisku ruky". *Rehabilitácia,* 55(2). pp 68-78. ISSN 0375-0922.

Český statistický úřad. (2023). *"Senioři v ČR v datech". Odbor statistiky trhu práce a rovných příležitostí".* https://www.czso.cz/csu/czso/vekove-slozeni-obyvatelstva.

Daňková, Š., Pastucha, D. (2018). "Robot assisted rehabilitation in post stroke patients with upper limb paresis". *Neurologie pro praxi*. 19 (4). pp 290-293. doi:10.36290/neu.2019.054. ISSN 1213-1814.

Deschenes, M. R. (2004). "Effects of aging on muscle fibre type and size". *Sports medicine.* 34 (12). pp 809-824. doi:10.2165/00007256-200434120-00002. ISSN: 0112-1642.

Feix, T. et al. (2016). "The GRASP Taxonomy of Human Grasp Types". *IEEE Transactions on Human-Machine Systems*. 46 (1), 66-77. doi:10.1109/THMS.2015.2470657. E-ISSN 2168-2305.

Gaul Aláčová, P. et al. (2023). "Vliv pohybové aktivity na kvalitu života u osob vyššího věku – pilotní studie". *Rehabilitácia 60*(4). pp 302-309. doi:10.61983/lcrh.v60i4.23. ISSN 0375-0922.

Gassert, R., Dietz, V. (2018). "Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective". *J Neuroeng Rehabil.* 15 (1), 46. doi:10.1186/s12984-018-0383-x. E-ISSN 1743-0003.

Holtrop, J. L. et al. (2014). "Investigating Age-related changes in fine motor control across different effectors and the impact of white matter integrity". *NeuroImage*. 96. pp 81-87. doi: 10.1016/j.neuroimage.2014.03.045. E-ISSN 1095-9572.

Hoogendam, Y. Y. et al. (2014). "Older Age Relates to Worsening of Fine Motor Skills: A Population-Based Study of Middle-Aged and Older adults Persons". *Front Aging Neurosci*. 6. doi:10.3389/fnagi.2014.00259.

Chen, S. et al. (2024). "Cortical activity in patients with high-functioning ischemic stroke during the Purdue Pegboard Test: insights into bimanual coordinated fine motor skills with functional near-infrared spectroscopy". *Neural regeneration research*. 19 (5). pp 1098-1104. doi: 10.4103/1673-5374.385312. ISSN 1673-5374.

Ju, F. et al. (2023). "The Use of Sports Rehabilitation Robotics to Assist in the Recovery of Physical Abilities in Older adults Patients with Degenerative Diseases: A Literature Review". *Healthcare (Basel).* 11 (3). doi:10.3390/healthcare11030326. ISSN 2227-9032.

Kikkert, S. et al. (2016). "Revealing the neural fingerprints of a missing hand". *ELife*, 5. doi:10.7554/eLife.15292. ISSN 2050-084X.

Klobucká, S. et al. (2022). „Pokročilé rehabilitačné technológie v terapii cievnych mozgových príhod". *Rehabilitácia,* 59(3). pp 183-197. ISSN 0375-0922.

Konečný, P. et al. (2017). "Robotická rehabilitace spasticity ruky". *Rehabilitace a fyzikální lékařství.* 24 (1). pp19-22. ISSN 1211-2658.

Kopřivová, J., Grmela, R. (2015). "Psychomotorika v práci se seniory". *Tělesná kultura*. 38 (2). pp 25-35. doi:10.5507/tk.2015.007. ISSN 1211-6521.

Krivošíková, M. (2011). *Úvod do ergoterapie*. Praha: Grada. ISBN 978-80-247-2699-1.

Levin, M. F., et al. (2015). "Emergence of virtual reality as a tool for upper limb rehabilitation: incorporation of motor control and motor learning principles". *Physical therapy*. 95 (3). pp 415-425. doi:10.2522/ptj.20130579. ISSN 1538-6724.

Li, L. et al. (2022). "Effect of pinch types on pinch force sense in healthy adults". *Front Hum Neurosci*. 16, 990431. doi:10.3389/NHAum.2022.990431. ISSN 1662-5161.

Lo, A. C. et al. (2010). "Robot-assisted therapy for long-term upper-limb impairment after stroke". *New Eng J Med*. 362 (19). pp 1772-1783. doi:10.1056/NEJMoa0911341. ISSN 0028-4793.

Mehrholz, J. et al. (2018). "Electromechanical and robot-assisted arm training for improving activities of daily living, arm function, and arm muscle strength after stroke". *Cochrane Database Syst Rev.* 9. doi: 10.1002/14651858.CD006876.pub5. ISSN 1469-493X.

Mlíka, R., et al. (2023). Multisensory integration/ Multisenzorická integrace. *Rehabilitácia*, 60(1). pp. 35-37 a 39-50. doi: 10.61983/lcrh.v60i1.33. ISSN 0375-0922.

OECD. (2019). "The future of aging: Opportunities and challenges for public policy". *OECD Publishing*. https://www.oecd.org/en/topics/ageing.html.

Radder, B. et al. (2019). "Home rehabilitation supported by a wearable soft-robotic device for improving hand function in older adults: A pilot randomized controlled trial". *PLOS ONE*. 14 (8). doi: 10.1371/journal.pone.0220544. E-ISBN 1932-6203.

Rantanen, T. (2003). "Muscle strength, disability and mortality". *Scand J Med Sci Sports*. 13 (1). pp 3-8. doi:10.1034/j.1600-0838.2003.00298.x. ISSN 1600-0838.

Rodriguez-de-Pablo, C. et al. (2012). "Development of computer games for assessment and training in post-stroke arm telerehabilitation". *2012 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. pp 4571-4574. doi:10.1109/EMBC.2012.6346984.

Seidler, R. D. et al. (2010). "Motor control and aging: Links to age-related brain structural, functional, and biochemical effects". *Neurosci Biobehav Rev*. 34 (5). pp 721-733. doi: 10.1016/j.neubiorev.2009.10.005. ISBN 0149-7634.

Shankar, R. et al. (2024). "Cost-Effectiveness Analysis of Robotic Exoskeleton Versus Conventional Physiotherapy for Gait Rehabilitation in Patients with Stroke and Spinal Cord Injury". *International Journal of Integrated Care*. 24 (4), 235. doi:10.5334/ijic.APIC3212. ISSN-E 1568-4156.

Schmidt, R. A., et al. (2019). *Motor control and learning: a behavioral emphasis* (6th ed). Human Kinetics. ISBN 9781492547754.

Schreuders, T., et al. (2007). "The Intrinsic Muscles of the Hand". *Physikalische Medizin, Rehabilitationsmedizin, Kurortmedizin*. 17 (1), 20–27. doi:10.1055/s-2007-940011. ISSN 1439-085X.
STARGEN EU (2022). "PABLO® X2". https://www.stargen-eu.cz/rehabilitace/horni-koncetina/pristroje-rady-tyro/pablo-x2/.
Su, T. et al. (2024). Effect of Upper Robot-Assisted Training on Upper Limb Motor, Daily Life Activities, and Muscular Tone in Patients with Stroke: A Systematic Review and Meta-Analysis. *Brain Behav*. 14 (11). doi:10.1002/brb3.70117. ISSN 2162-3279.
Swinnen, S. P., Gooijers, J. (2015). "Bimanual Coordination". In **A. W. Toga** (ed): *Brain Mapping: an Encyclopedic Reference, vol. 2,* pp 475-482. Elsevier. doi:10.1016/B978-0-12-397025-1.00030-0. ISBN 0123970253, 9780123970251.
Vanoglio, F. et al. (2017). "Feasibility and efficacy of a robotic device for hand rehabilitation in hemiplegic stroke patients: a randomized pilot controlled study". *Clinical rehabilitation*. 31 (3), 351–360. doi:10.1177/0269215516642606. ISSN: 0269-2155.
Vergara, M. et al. (2014). An introductory study of common grasps used by adults during performance of activities of daily living. *J Hand Ther*. 27 (3), 225–234. doi: 10.1016/j.jht.2014.04.002. ISSN 1545-004X.
Vyskotová, J., Macháčková, K. (2013). *Jemná motorika: vývoj, motorická kontrola, hodnocení a testování*. Praha: Grada. ISBN 978-80-247-4698-2.
Vyskotová, J. et al. (2021). *Terapie ruky.* Olomouc: Univerzita Palackého. ISBN 978-80-244-5767-3.
WORLD HEALTH ORGANIZATION. (2021). "*Ageing and health"*. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.
Zhang, C., et al. (2017). Robotic approaches for the rehabilitation of upper limb recovery after stroke: a systematic review and meta-analysis. *Int Journal Rehabil Res.* 40 (1). pp 19-28. doi: 10.1097/MRR.0000000000000204. ISSN: 0342-5282.