EFFICIENCY OF LEG EXOSKELETON USE IN REHABILITATION OF CEREBRAL STROKE PATIENTS

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EFIKASNOST UPOTREBE EGZOSKELETA NOGE U REHABILITACIJI PACIJENATA KOJI SU PRETRPELI MOŽDANI UDAR

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ABSTRACT

The study aimed to *evaluate the effectiveness of functional and motor activity restoration, including the walking function, in patients after an ischemic stroke using the ExoAtlet lower limb exoskeleton.* ***Patients and methods.*** *A clinical study was carried out on 42 patients who had undergone a cerebral infarction in the mid cerebral artery system with a post-stroke paresis of the leg, and who had undergone a rehabilitation course in a round-the-clock hospital during the early recovery period. Patients were randomized into two equal groups comparable in terms of the stroke severity: the patients in group 1 were receiving a standard rehabilitation program (control group), the patients in group 2 were additionally receiving a course of gait rehabilitation using the ExoAtlet exoskeleton - 10 sessions, 5 sessions per week for 14 days.* ***Results.*** *The study demonstrated the effectiveness of the ExoAtlet exoskeleton used in the rehabilitation of stroke patients over the standard course of rehabilitation. The advantages include a decrease in the hemiparesis degree, an increase in the muscle strength of the paretic limb, an improvement in balance, an improvement and acceleration of the walking process. The obtained results of the instrumental study confirmed the benefits of physical training on the Exoskeleton, which was demonstrated through an increase in stability and balance, as well as through a decrease in the energy consumption index for maintaining the stable verticalization.* ***Conclusion.*** *The usage of the ExoAtlet exoskeleton increases the effectiveness of rehabilitation measures and improves motor and functional activities of patients who have suffered a cerebral stroke.*

Keywords: *stroke, rehabilitation, exoskeleton, ExoAtlet, walking, stabilometry.*

SAŽETAK

Ova studija je imala za cilj da proceni efikasnost ponovnog vraćanja finkcionalne i motorne aktivnosti, uključujući funkciju hodanja kod pacijenata koji su pretrpeli ishemijski moždani udar korišćenjem ExoAtlet egzoskeleta za donje udove. ***Pacijenti i metode.*** *Klinička studija je sprovedena na 42 pacijenta koji su pretrpeli ishemijski moždani udar u sistemu srednje cerebralne arterije sa parezom noge nakon moždanog udara i koji su prošli kroz tok rehabilitacije uz neprekidnu negu u bolnici tokom početnog perioda oporavka. Pacijenti su nasumično raspoređeni u dve jednake grupe koje su mogle da se porede u smislu jačine moždanog udara: pacijenti u prvoj grupi su dobijali standardni rehabilitacioni program (kontrolna grupa), pacijenti u drugoj grupi su dobijali dodatno i rehabilitaciju za hod uz korisćenje ExoAtlet egzoskeleta – 10 sesija, 5 sesija nedeljno 14 dana.* ***Rezultati.*** *Studija je pokazala efikasnost ExoAtlet egzoskeleta koji se koristi u rehabilitaciji pacijenata koji su pretrpeli mozdani udar u odnosu na standardni tok rehabilitacije. Prednosti uključuju smanjenje u stepenu hemipareze, povećanje u mišićnoj snazi paretičnog uda, poboljsanje u ravnoteži, poboljsanje i ubrzavanje procesa hodanja. Dobijeni rezultati instrumentalne studije potvrđuju koristi fizičkog treniranja na egzoskeletu što je pokazano kroz povećanje u stabilnosti i ravnoteži kao i kroz smanjenje indeksa potrošnje energije za održavanje stabilne vertikalizacije.* ***Zaključak.*** *Upotrebom ExoAtlet egzoskeleta povećava se efikasnost mera rehabilitacije i povećavaju se motorne i funkcionalne aktivnosti pacijenata koji su pretrpeli moždani udar.*

Ključne reči: *moždani udar, rehabilitacija, egzoskelet, ExoAtlet, hodanje, stabilometrija.*

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INTRODUCTION

In recent decades, a stroke has become an acute medical and social problem all over the world. The figures for stroke cases are growing primarily in economically developed countries and this may be explained not only as an increase in life expectancy (1, 2). An increase in social interactions, constant stress, and brain overload has raised the number of strokes in young patients, most often engaged in mental work (3-5). Any successful introduction of new pharmacological, surgical, and X-ray endovascular methods of the stroke treatment, has been leading to a new problem - a significant increase in the number of patients with disabilities (6-8). Therefore, in recent years, some acute questions have been raised regarding the effectiveness of rehabilitation measures and reintegration of people with disabilities into society (9, 10).

The main disabling factor after the stroke is an impaired motor function, particularly, the walking function (10-12). As a result of the stroke unilateral muscle weakness, imbalance in the movement coordination due to uneven distribution of the body weight, sensory disturbances, post-stroke spasticity, aggravating fear of falling have been observed (13-14). Muscle weakness, combined with spasticity and violation of the correct reciprocal innervation, makes it impossible to implement an automated walking pattern and reduce imbalance, which significantly disrupts the physical activity of patients, restricts their social and daily activity (14-16). That is why the walking function rehabilitation is an important component for resocialization and improvement of life quality for patients. Despite the foundation of new rehabilitation centers and the emergence of new modern methods to restore lost motor functions, more than a third of patients cannot restore the ability to walk independently after the rehabilitation. Therefore, our search for new technologies of the motor function rehabilitation continues.

One of the prospective research areas that has emerged at the intersection of technology and medicine is the creation of exoskeletons - devices with the built-in electronic systems that may allow partial replacement of lost motor functions as a result of illness. The technical implementation of these devices is done in different ways: both simple mechanical devices and complex ones have been created using the brain-computer neuro-interfaces (17-20). However, at present, a sufficient amount of clinical data has not been collected yet, which prevents us from the objective calculation of the effectiveness of different types of such devices and determination of certain clinical groups in which the usage of exoskeletons will be most effective.

The aim of the study was to evaluate the effectiveness of restoring the functional and motor activity, including the walking function, in patients after the ischemic stroke in the middle cerebral artery basin using the ExoAtlet lower limb exoskeleton during the early recovery period after the stroke compared with the traditional methods of rehabilitation.

PATIENTS AND METHODS

The study was designed as a clinical prospective study. The research included 42 patients aged between 45 and 75 years (the mean age 61.2 ± 9.3 years, median - 63 years) who had suffered the cerebral infarction, who had undergone a course of rehabilitation in a 24-hour working hospital in the early recovery period of the stroke. The study was approved by the Independent Ethics Committee at the State Budgetary Institution of Healthcare in the Moscow Region "Moscow Regional Research Clinical Institute named after M.F. Vladimirsky" (the protocol No. 6 of 15.06.2017).

The mandatory inclusion procedure involves signing of patients' voluntary informed consent, the ischemic stroke in the middle cerebral artery system confirmed by neuroimaging (CT/MRI of the brain) without signs of the hemorrhagic transformation, the presence of spastic hemiparesis or leg monoparesis, muscle strength - 3-4 points according to the Medical Research Council Scale (MRCS), the degree of functional activity/disability - 2-3 points on the modified Renkin scale and 70-95 points on the Bartel index (mild to moderate disability), as well as preserved cognitive functions (25-30 points on the Mini-Mental State Examination). Besides that, the study included the patients who, according to the Hauser Ambulation Index, were ranging from 3 points (the patient can walk without assistance, in the meantime, he could walk 8 meters in 11-20 seconds) to 6 points (the patient needed double-sided support and more than 20 seconds to walk 8 meters).

The study did not include patients outside the inclusion criteria, and who were not able to walk 10 meters even with bilateral assistance, who had a severe comorbid status, the obesity rate ≥ II, who had the presence of critical stenosis of great vessels of the head (≥ 70% of lumen diameter), dementia, depression, low level of motivation to participate in the rehabilitation training.

The patients were simply randomized into two identical groups.

The patients of the 1st group, the Comparison group (n = 21) received the standard rehabilitation program, which included the physical therapy, exercise therapy, massage, sessions with a speech therapist and a medical psychologist, as well as the cognitive training and secondary prevention of the ischemic stroke by drugs. The walking training on a flat surface was carried out 5 days a week for 2 weeks, the duration of each lesson varied within 20-40 minutes, depending on the patient's functional capabilities.

The patients of the 2nd group, the main group (n = 21), received the course of gait restoration using the ExoAtlet exoskeleton (ExoAtlet Company, Russia) - the complex robotic mechanotherapy (Fig. 1) in addition to the standard rehabilitation scheme. The sessions varied within 10-30 minutes, were focused on the somatic and functional state of each

patient, and were increased in the duration of each subsequent session. The total number of sessions was 10 and spread over 2 weeks (5 per week). The physical activity was being increased daily, depending on the condition and endurance of the patient.

Figure 1. A patient walking with the ExoAtlet exoskeleton during the rehabilitation session.



Under the study protocol, two control points were identified: (1) - before the start of the study (the inclusion of the patient in the study, randomization), (2) - day 14, after the end of the rehabilitation course. The study duration was 14 days for all patients.

At the control points of the study, muscle strength in the lower extremities was assessed using the Medical Research Council Scale (MRCS) (21); the functional assessment was done according to the Rankin scale (22) and the Bartel index of daily activity (23); the safety of the walking function was measured according to the Hauser Ambulation Index (HAI) (24), the study of stability and balance was performed using the Berg Balance Scale (BBS) (25). In addition to the clinical examination and assessments on various scales, the dynamics of motor function restoration were recorded using a stabiloplatform, and the dynamics of walking speed (10-meter walking test, 10MWT) were also obtained using a stopwatch (26). Using an instrumental study of stabilometry (stabiloplatform "ST-150", Mera-TSP, Russia), the state of vertical stability was studied, evaluating such indicators as the length of the statokinesiogram (L, mm) - the length sum of the segments that connect all projection points of a patient's pressure center on the surface of the stabiloplatform in the coordinate system during the functional test; the surface area of the statokinesiogram (S, mm2) which accounts for 90-95% of all positions of the pressure center during the study, is determined by calculating the area of the ellipse; the energy consumption index (Ei, J) - an indicator of energy consumption for the movement of the general pressure center during the study, calculated as the sum of increments of kinetic energies of the subject's body, was counted for each elementary movement of the general center of pressure. These indicators were obtained via two functional tests - a simple uncomplicated Romberg test, 2 consecutive 51-second phases of calm vertical standing with open and closed eyes, in the "European" feet placement (27, 28).

At the time of inclusion into the study, both patient groups were indistinguishable in terms of functional and motor capabilities (Table 1), which made it possible to conduct an objective comparative statistical analysis.

Table 1. The patient groups` characteristics according to the assessments via different scales and tests at the time of inclusion into the study.

Indicator		Statistical characteristic	Group1 Comparison (n=21)	Group 2 Exoskeleton (n=21)	p
Muscle strength, The Medical Research Council Scale, score		Me (Q1 : Q3)	4 (3 : 4)	4 (3 : 4)	0,750
The Bartel index, score		Me (Q1 : Q3)	80 (75:85)	80 (70:85)	0,746
The Berg Balance Scale, score		Me (Q1 : Q3)	41 (41 : 45)	41 (41 : 46)	0,939
The Rankin Scale, score	2 3	n (%)	3 (14,3%) 18 (85,7%)	4 (19,0%) 17 (81,0%)	0,682

Indicator		Statistical characteristic	Group1 Comparison (n=21)	Group 2 Exoskeleton (n=21)	p
The Hauser Ambulation Index, score	3 4 5 6	n (%)	4 (19,0%) 11 (52,4%) 6 (28,6%) 0	4 (19,0%) 9 (42,9%) 7 (33,3%) 1 (4,8%)	0,544
10-meter walking test, sec		Me (Q1 : Q3)	23 (18 : 23)	22 (18 : 23)	0,406

The baseline stabilometry indicators which were recorded in patients at the moment of the inclusion into the study, were also statistically indistinguishable in both groups ($p > 0.05$), with the exception in the index of energy expenditure with eyes closed, which was 1.5 times higher in the Comparison group (Table 2). In this regard, the analysis of the stabilometry indicators was carried out by both the absolute values of L, S, and Ei, determined on the 14th day, and by the percentage change dynamics in the observed parameters concerning the initial data.

Table 2. The baseline stabilometry indicators before the rehabilitation program in both groups.

Indicator	Statistical characteristic	Group 1 Comparison (n=21)	Group 2 Exoskeleton (n=21)	p
The length with eyes open, mm	Me (Q1 : Q3)	549 (538 : 564)	507 (503 : 513)	0,059
The length with eyes closed, mm	Me (Q1 : Q3)	730 (567 : 899)	598 (515 : 615)	0.071
The area with eyes open, mm^2	Me (Q1 : Q3)	339 (270 : 470)	319 (235 : 509)	0.658
The area with eyes closed, mm^2	Me (Q1 : Q3)	399 (273 : 498)	258 (242 : 471)	0.075
Energy consumption to keep balance with eyes open, J	Me (Q1 : Q3)	8.7 (5.7 : 12.1)	7.1 (6.3 : 16.0)	0.791
Energy consumption to keep balance with eyes closed, J	Me (Q1 : Q3)	19.9 (16.0 : 22.0)	13.8 (11.1 : 16.5)	0.005

Statistical processing of the research results was carried out using the SPSS 23.0 software. The differences were considered to be significant at $p < 0.05$. The descriptive statistics of the continuous quantitative data are presented as the mean (M) and standard deviation (± SD) with the normal distribution, as well as the median (Me), values of the lower (25%, Q1) to the upper (75%, Q3) quartiles with the abnormal distribution. To compare the quantitative indicators of two independent samples, the Mann-Whitney test was used, to compare the indicators of two related ones - the Wilcoxon test. The qualitative variables were analyzed in absolute and relative (by percent) units and compared using the $\chi 2$ test (the analysis of the contingency tables).

RESULTS

During the study, a significant positive effect of the Exoskeleton physical activity training was recorded in the dynamics of muscle strength, assessed by the Medical Research Council Scale (MRCS) (Table 3). An improvement in the MRCS score during 14 days was achieved by the majority (71.4%) of patients of the Exoskeleton group, whilst the improvement was recorded only in 28.6% of the Comparison group cases, and mostly, patients didn`t demonstrate changes in the limb paresis dynamics. ($p < 0.05$).

The full recovery of muscle strength in the limbs on the 14th day of the study was noted in 7 (33.3%) patients of the Exoskeleton group and only in 1 case (4.8%) in the Comparison group ($p < 0.05$).

Table 3. The assessment of muscle strength in the lower extremities using the Medical Research Council Scale on the 14th day of the study (n,%).

		Comparison	Exoskeleton	p
The MRCS score	3 4 5	3 (14,3%) 17 (81,0%) 1 (4,8%)	0 14 (66,7%) 7 (33,3%)	0,006
Dynamics	No changes Improvement	15 (71,4%) 6 (28,6%)	6 (28,6%) 15 (71,4%)	0,011

The study paid a particular attention to the assessment of the gait function. Conducting a 2-week rehabilitation course with the additional inclusion of 10 ExoAtlet sessions into the program led to a significant improvement in the patients' physical activity. The improvement in walking measured according to the Hauser index scale was observed in 15 (71.4%) cases in the Exoskeleton group, which is 3.8 times more than in the Comparison group where the improvement was recorded in 4 (19.0%) cases. ($p < 0.05$). Only in the Exoskeleton group, there were some patients (14.3%) who, by the end of the rehabilitation course, could walk 8 meters in less than 10 seconds, and gait disturbances were insignificant and almost imperceptible.

The walking speed test at a distance of 10 meters also confirmed the effectiveness of rehabilitation on the ExoAtlet Exoskeleton. On average, in the Exoskeleton group, the 10-meter distance was covered 18% faster (4 seconds), decreasing from 22 seconds on the day 0 to 18 seconds on the day 14 ($p < 0.001$). The patients walking speed in the Comparison group was also improved, but this improvement was 2 times less than in the Exoskeleton group ($p < 0.05$) (Table 4).

Table 4. The assessment of walking according to the Hauser Ambulation Index and 10-meter walking test on the 14th day of the study.

			Comparison	Exoskeleton	p
The Hauser Ambulation index,n (%)	Score	2 3 4 5 6	0 4 (19,0%) 15 (71,4%) 2 (9,5%) -	3 (14,3%) 11 (52,4%) 3 (14,3%) 4 (19,0%) -	0,039
	Score dynamics	No changes 1 score 2 scores	17 (81,0%) 4 (19,0%) 0	6 (28,6%) 12 (57,1%) 3 (14,3%)	0,001
10-meter walking test, sec Me (Q1 : Q3) 95CL		Speed on day 14	21 (14 : 21) 11-25	18 (13 : 21) 13-24	0,045
		Dynamics, -sec	2 (2:3) 0-5	4 (2:5) 2-7	0,007*

The Berg balance scale indices did not reveal any significant intergroup differences, the average score on the 14th day was 46 (46: 50) in the Comparison group and 47 (45: 56) in the Exoskeleton group ($p > 0.05$). However, after analyzing the indicator dynamics, a difference was recorded and expressed as an improvement in the balance dynamics by 7 points averagely in the Exoskeleton group and by 5 points in the Comparison group. The 2 points difference was statistically significant ($p < 0.05$).

As a result, a decrease in the disability degree and an improvement in the social adaptation were found in both groups, but the decrease was better expressed in the Exoskeleton group. Thus, the average score on the Bartel index in the Comparison group was 85 (80:95) points, in the Exoskeleton group - 90 (75: 100) points. Although the 5 points difference did not showany statistical significance, the frequency assessment of adaptation`s complete recovery revealed the significance. 100 points according to the Bartel index in the Comparison group were observed in 3 (14.3%) patients, in the Exoskeleton group - in 10 (47.6%) patients, which is 3.3 times more ($p < 0.05$). The analysis of the disability level according to the modified Rankin scale on the day 14 also showed a significant effect of the Exoskeleton rehabilitation course on the disability degree of the stroke patients. The improvement in the functional activity according to Rankin was found in 3 (14.3%) cases in the Comparison group and in 9 (42.9%) cases in the Exoskeleton group, which is significantly 3 times higher ($p < 0.05$) (Table 5).

Table 5. The assessment of the functional activity efficiency according to the modified Rankin scale on the 14th day of the study (n, %).

	Comparison	Exoskeleton	p
Me (Q1 : Q3)	3 (2:3)	2 (2:3)	0,028
Score 1 2 3	0 6 (28,6%) 15 (714%)	1 (4,8%) 12 (57,1%) 8 (38,1%)	0,025
No changes Improvement	18 (85,7%) 3 (14,3%)	12 (57,1%) 9 (42,9%)	0,043

Throughout the instrumental study of the stabilometric indicators (length, area of statokinesiogram, index of energy consumption), significant intergroup differences were recorded in the functional tests, which the patients hadperformed with both open and closed eyes. The recorded differences showed a positive effect of exercises on the Exo-Atlet exoskeleton, the greatest differences were registered with eyes open (Table 6).

Table 6. The stabilometry indicators on the 14th day of the study.

		Comparison	Exoskeleton	p
Length (L) with eyes open	Day 14, mm	492 (475: 537)	376 (343 : 393)	**<0,0001**
	Dynamics by day 14, %	-12.5 (-15.8: -1.5)	-26.7 (-39.1: -24.9)	**<0,0001**
	- decrease - increase	17 (81,0%) 4 (19,0%)	21 (100%) 0	0.053
Length (L) with eyes closed	Day 14, mm	663 (398: 780)	423 (348 : 553)	**0,021**
	Dynamics by day 14, %	-18,6 (-26,9: -11,3)	-28,9 (-31,4: -22,4)	**0.045**
	- decrease - increase	20 (95.2%) 1 (4.8%)	19 (90.5%) 2 (9.5%)	0.500
Surface area (S) with eyes open	Day 14, mm2	315 (210: 346)	154 (123 : 231)	**<0,0001**
	Dynamics by day 14, %	-22,2 (-32,9: -13,3)	-54,6 (-61,4: -48,9)	**<0,0001**
	- decrease - increase	16 (76.2%) 5 (23.8%)	19 (90.5%) 2 (9.5%)	0.205
Surface area (S) with eyes closed	Day 14, mm2	352 (200 : 374)	232 (110 : 242)	**0,001**
	Dynamics by day 14, %	-26,7 (-29,6: 1,4)	-46,2 (-54,5: -6,2)	0.071
	- decrease - increase	13 (61.9%) 8 (38.1%)	17 (81.0%) 4 (19.0%)	0.153
Energy consumption index (Ei) with eyes open	Joule	7.5 (6.0: 10.8)	4.1 (3.5 : 5.0)	**<0,0001**
	Dynamics in %	-13,8 (-17,4: -1,8)	-61,1 (-68,7: -29,6)	**<0,0001**
	- decrease - increase	16 (76.2%) 5 (23.8%)	21 (100%) 0	**0.024**
Energy consumption index (Ei) with eyes closed	Joule	11.0 (9.7 : 16.5)	7.2 (3.1 : 12.2)	**<0,0001**
	Dynamics in %	-34,0 (-39,4: -25,7)	-51,2 (-71,3: -37,7)	**0.007**
	- decrease - increase	17 (81,0%) 4 (19,0%)	18 (85.7%) 3 (14.3%)	0.500

DISCUSSION

The figures for the statokinesiogram length on the 14th day of the study in the Comparison group were 1.31 times larger on average with eyes open ($p < 0.05$), and 1.57 times larger with eyes closed ($p < 0.05$) than in the Exoskeleton group. Meanwhile, within the Comparison group, the statokinesiogram length with eyes open decreased by 12.5% on average, within the Exoskeleton group - by 26.7% concerning the initial values that had been recorded before the start of the rehabilitation course, the 2.14 times difference is statistically significant and indicates the positive impact of the Exoskeleton training. With eyes closed, the statokinesiogram length dynamics were more significant: the reduction in length in the Comparison group was 18.6%, in the Exoskeleton group - 28.9% (1.55 times higher, $p < 0.05$). It is also important to note that the statokinesiogram length indicator with eyes open became worse by the day14 in 19% of the cases in the Comparison group, but there were no such cases recorded in the Exoskeleton group.

The statokinesiogram area on the 14th day was averagely higher for the Comparison group, 2.05 times more with eyes open ($p < 0.05$) and 1.52 times more with eyes closed ($p < 0.05$). In the Comparison group, the statokinesiogram area with eyes open decreased by 22.2% on average, in the Exoskeleton group - by 54.6% compared to the initial values, the 2.46 times difference is statistically significant ($p < 0.05$). With eyes closed, the area decreased by 26.7% in the Comparison, and by 46.2% in the Exoskeleton groups, respectively. It is interesting to note the tendency of a 2-2.5-fold reduction in the number of patients whose statokinesiogram area worsened by the day 14 (with eyes open, there were 23.8% of such cases in the Comparison group, and 9.5% of cases in the Exoskeleton group; with eyes closed - 38, 1% and 19.0% of cases, respectively, $p > 0.05$). The findings confirm the improved resilience of patients receiving the Exoskeleton training.

The energy consumption index for maintaining the stable verticalization on the 14th day of the study also became significantly better in the functional tests for both eyes closed and open ($p < 0.05$) in the Exoskeleton group. On average, the patients in the Comparison group were spending 1.83 times more energy with eyes open, and 1.53 times with eyes closed ($p < 0.05$). Simultaneously, in the Comparison group, the energy consumption index with eyes open averagely decreased by 13.8%, in the Exoskeleton group - it dropped by 61.1% compared to 1 day, which is 4.42 times higher ($p < 0.05$). The same indicator for eyes closed demonstrated the improvement in the Comparison group by 34.0% on average, in the Exoskeleton group it was 1.51 times more, 51.2% compared with the initial figures ($p < 0.05$). We would like to emphasize that with eyes open, the energy consumption index diminished in 23.8% of cases of the Comparison group, no such cases were recorded in the Exoskeleton group ($p < 0.05$).

Our clinical prospective pilot comparative study demonstrated the effectiveness of the ExoAtlet exoskeleton in the rehabilitation of patients after the middle cerebral artery system stroke. The advantages over the standard rehabilitation course include the decrease in the hemiparesis degree, the increase in the paretic limb muscle strength, the improvement in balance, the improvement and acceleration of walking, which ultimately made it possible to increase the degree of social adaptation and reduce the degree of disability. The obtained results of the instrumental study confirmed the benefits of the Exoskeleton physical training, which were expressed by the increase in stability and balance (a more pronounced reduction in the statokinesiogram length and area) by 1.3-2.0 times, as well as in the decrease in the energy consumption for maintaining the stable verticalization by 1.5-1.8 times with eyes open and closed. The degree of the established intergroup differences allows us to conclude that 10 additional sessions on the ExoAtlet for 2 weeks of rehabilitation during the early recovery period of the stroke for patients with mild and moderate disadaptation, increase the effectiveness of the physical activity rehabilitation till 15-20%. This could increase the number of patients with full functional and motor recovery.

CONCLUSION

The use of the ExoAtlet exoskeleton increases the effectiveness of rehabilitation measures and improves the motor and functional activity of patients who have suffered the cerebral stroke. Therefore, it can probably be recommended for permanent inclusion in the rehabilitation program for patients after the stroke. However, for the final decision of both the inclusion itself and the modes of use of the ExoAtlet exoskeleton, it is necessary to conduct a more in-depth study on protocols that meet the requirements of the principles of evidence-based medicine. In particular, it is advisable to conduct a control-spawning study of several groups of patients undergoing the rehabilitation using other robotic technologies, as well as technologies used in exoskeletons.

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