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Change in patients' psychophysical performance following lumbar discectomy relative to the postoperative rehabilitation programme

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Purpose: The aim of this study was to assess the change in psychophysical performance of patients after lumbar discectomy in relation to the postoperative rehabilitation programme. *Methods*: The study involved 60 participants randomly divided into two groups of 30 individuals. Both groups participated in a basic version of the rehabilitation programme, and individuals in the study group additionally received manual therapy. The evaluation was performed twice, before the start and after the completion of the 3-month rehabilitation programme. The tests were carried out to measure static balance, functional status using Oswestry Disability Index (ODI) and Roland-Morris Disability Questionnaire (RMDQ), lumbar spine range of motion using the original Schober's test and the intensity of pain using the Visual Analogue Scale (VAS). *Results*: Both groups showed significant improvement in most of the psychophysical parameters assessed (study versus control $p < 0.01$, $p < 0.05$), except for the parameters of balance. In the study group, significant changes occurred in all parameters except X average, Area circular and average velocity in trials with eyes closed and left leg stance after rehabilitation ($p < 0.05$). The findings showed significant differences in the reduced pain intensity on the VAS ($p = 0.0001$), improved functional status in ODI and improved static balance ($p < 0.01$), in favour of the study group. *Conclusions*: The protocol which additionally included manual therapy was found to be more effective than the basic programme. Its superiority was reflected by greater pain reduction, more visibly improved functional status as well as improved static balance.

Key words: *lumbar, rehabilitation, therapy, pain*

Abbreviations

ODI – functional status using Oswestry Disability Index,
RMDQ – Roland–Moris Disability Questionnaire,
VAS – Visual Analogue Scale,
HNP – herniated nucleus pulposus,
AMTI – the force plate from Advanced Medical Technology,
COP – the Centre of Pressure of the foot.

1. Introduction

Lumbar pain is one of the most common problems leading to reduced quality of life. Its consequences include decrease in physical activity, which adversely affects the production of hormones in the adrenal cortex and contributes to poor mood, possibly even leading

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to depression [22]. In many of these patients, a herniated nucleus pulposus (HNP) is the underlying cause of pain in the sacrum area. Conservative treatment is effective in a vast majority of patients with HNP. A surgical procedure is necessary for a much smaller percentage of patients, although in absolute numbers this is still a large group of patients. The most typical surgery in the case of HNP is lumbar discectomy, which is one of the most commonly performed procedures in neurosurgery and spine surgery in general [22]. It is highly effective in reducing HNP related pain, known as sciatica. Approximately 30 000 procedures are performed annually in Poland, compared to 90 000 in South Korea [13]. Revision procedures four years after discectomy are performed at a rate of 7.1–12% [13], [24].

Functional outcomes of the surgery can be improved by well-designed postoperative exercise, as shown by a systematic review listed in the Cochrane Database [28]. However, many patients in Poland and in other countries receive little or no formal rehabilitation after the surgery [36]. Moreover, the problems faced by the surgeons performing the procedure and the physiotherapists taking care of the patients after the surgery are associated with the lack of standards or recommendations for postoperative rehabilitation. Additionally, inadequate postoperative rehabilitation can thwart the positive effect of the surgical procedure. In clinical practice, there are no evidence-based protocols available to surgeons or physiotherapists for rehabilitation after spinal surgery. The scientific literature in this area is scarce [1], [2], [6], [9], [11], [14], [26], [27], [32]. There are a few randomised clinical studies investigating the effects of rehabilitation on the functional performance of patients following discectomy as well as their return to work [1], [2], [6], [9], [11], [14], [26], [27], [32]. However, no research reports assess the effects of kinesiotherapy combined with elements of manual therapy and physical therapy which are investigated in the present study.

The aim of this study was to assess the change in psychophysical performance of patients after lumbar discectomy in relation to the postoperative rehabilitation programme.

2. Materials and methods

2.1. Participants and setting

The study was conducted in the Neurosurgery Clinical Hospital of the University of Rzeszów, St. Luke's Regional Hospital in Tarnów and in Reha Medica Rehabilitation Centre in Tarnów, Poland. Sixty participants enrolled for the study were randomly divided into two groups, each with 30 individuals. Both groups participated in the basic version of the rehabilitation programme, and individuals in the study group additionally received manual therapy.

The following inclusion criteria were applied: diagnosed intervertebral disc injury in L4–L5 or L5–S1 segments, no previous surgical intervention, age in the range of 18–65 years, no comorbidities or neurological deficits, no active cardiovascular disease and no contraindications to administration of physical medicine or manual therapy. The exclusion criteria were defined as follows: lack of informed consent to participate in the study, complications following the surgery, poor exercise tolerance (dizziness, nausea, reported decline of daily functioning), postoperative infections, and damaged nerves of the central nervous system.

2.2. Ethics

The experimental conditions were in accordance with the Declaration of Helsinki, and all participants provided informed written consent to participate in the study. Approval to conduct the study was obtained from the Bioethics Commission at the University of Rzeszów, Poland on April 12, 2018 (No. 4/12/2018) and all methods were performed in accordance with the relevant guidelines and regulations.

2.3. Procedures

The participants were randomly assigned to the study group (n = 30) and the control group (n = 30). Randomisation was performed using the software MATLAB (MathWorks, Inc. 2018, Massachusetts) with RARtool interface. The person responsible for randomization also managed the list of patients divided into groups and informed the physiotherapist in charge of training which patients were assigned to the experimental group and which to the control group. The individual administering the exercises did not participate in patient examinations or assessments. Initial and final assessments were conducted by a physiotherapist who was blinded to the subjects' group assignments and had no involvement in their training. The list of patients divided into groups was maintained by the researcher overseeing randomization. This list was decoded after the final assessment of the last qualified patient during the final examination. Prior to the start of the program, the research team was instructed not to disclose any information regarding assessments or the course of training. The rehabilitation programme applied in the control group comprised the standard physiotherapy procedure, physical therapy and exercise performed at home. The rehabilitation programme applied in the study group comprised the standard physiotherapy procedure, physical therapy, elements of manual therapy and exercise performed at home. The evaluation was performed twice, before the start and at the end of the rehabilitation, i.e., after three months.

2.4. Rehabilitation protocol

Postoperative rehabilitation was initiated on the 15th day after the surgery and was continued for three months, with 40-minute therapy sessions held twice a week. Until then, patients performed exercise at home following instruction received before they were discharged from the Neurosurgery Ward. These included: abdominal and thoracic breathing exercises, active and passive lower limb exercises, upper and lower limb exercises, learning to stand up, learning to stand upright.

The rehabilitation programmes were designed to comprise a few components, in the study group – kinesitherapy, physical therapy, home exercise, and elements of manual therapy, and in the control group – kinesitherapy, physical therapy and home exercise. Kinesitherapy (identical in both groups) included the following: plantar flexion and dorsiflexion of the foot, knee flexion, extension on a chair, walking on all fours, tightening the transverse abdominal muscle – deep stabilisation, hip muscle inhibition, stretching the gluteal muscles and piriformis muscle, pelvic mobilisation through stretching of the multifidus muscle, adductor ball squeeze, weighted breathing, drawing the knees to the chest, eccentric training of the quadriceps muscles, concentric and eccentric training of the gastrocnemius muscle and the tibialis anterior muscles using TheraBand as well as lumbar flexion and extension using exercise ball. Physical therapy (identical in both groups) included the following: local laser treatment, low-frequency magnetic field, local cryotherapy, electrotherapy: TENS in the operated area.

Manual therapy (only in the study group) included the following elements.

Myofascial techniques focused on the multifidus and oblique abdominal and small pelvic muscles and aimed to relax tensions and improve spinal stabilization (15% of the duration of a single therapy unit) [6], [30].

Hip joint mobilization focused on improving mobility and stability of the hip joint in order to increase the lower-body capacity (15% of the duration of a single therapy unit) [16], [19], [39].

Post-isometric relaxation (PIR) was applied to improve activation of the transversus abdominis and multifidus muscle particularly in the context of lumbar spine stabilization. The technique was designed to increase range of movement and improve spinal stability. Majority of the patients had an abnormal posture and often maintained a sitting position, which led to muscle tension disorders particularly of the transversus abdominis and in the multifidus muscle [23]. Post-isometric relaxation produces such positive effects as reduced muscle tension and increased range of motion, which is particularly important in the treatment of patients with back pain.

The duration of this intervention accounted for 15% of the total time per therapy session [17], [23], [29], [37].

Trigger point therapy focused on trigger points on the gluteal muscles (small, medium, large), piriformis muscle, muscles in the ischial and tibial group and multifidus muscle, in order to relieve the pain and improve mobility (15% of the duration of a single therapy unit) [30], [31].

Fascial techniques were applied in the area of the cervical, thoracic and lumbar spine and in lower extremities, in order to improve tissue flexibility and relieve tension (20% of the duration of a single therapy unit) [5].

Diaphragm mobilization aimed to improve respiratory function and core stability (10% of the duration of a single therapy unit) [33].

Neuromobilization of the sciatic nerve aimed to improve nerve mobility, which can help reduce pain and improve lower limb muscle function (10% of the duration of a single therapy unit) [18].

During the clinical trials no significant adverse events or complications were identified in the groups investigated. Regular monitoring of the participants' health status and their active cooperation with the treatment team made it possible to detect any possible adverse symptoms early, however none of the patients reported health problems.

2.5. Outcome measures

Effectiveness of the rehabilitation programme was evaluated by measuring the static balance on the force plate from Advanced Medical Technology Inc. (AMTI) [34], the functional performance using the Oswestry Disability Index (ODI) [7] and Roland-Morris Disability Questionnaire (RMDQ) [4], [10], [12]; lumbar spine range of motion with the original Schober's test

[18] and the intensity of pain on the Visual Analogue Scale (VAS) [34].

The measurement of static balance performed using AMTI involved continuous assessment of the Centre of Pressure (COP) of the foot. The analyses took into account the measures of the Average Load Point *Y* determining the anterior–posterior coordinates *Y* (*Y* average [cm]), the Average Load Point *X*, determining the lateral coordinates *X* (*X* average [cm]), Average COP velocity (*V* average [cm/s]), Path Length [cm] of the COP measured during the trial, and Area Circular, i.e., the area defined by the COP during the trial [cm^2]. Stabilography measurements, 30 seconds each, were performed in course of trials with double-leg stance and eyes open/closed, and with single-leg stance (right/left leg) with eyes open/closed. To avoid fatigue, the trials were separated with intervals of 30 seconds. To minimise any interferences or noise, the assessments were performed in a closed room. During the trials, the participants were instructed to stand on the platform and focus their gaze on a red target placed in front on the wall, at a distance of 4 feet (1.2 m). The force plate AMTI employed in the present study has been shown to be a valid instrument of a gold standard quality [34].

The participants' functional status was performed using Oswestry Disability Index (ODI) [7] and Roland–Morris Disability Questionnaire (RMDQ) [4], [10]. ODI contains ten questions, each with six answers scored from 0 to 5. When completing the questionnaire, the patient answers questions related to pain intensity, independence, lifting objects, walking, sitting, standing, sleeping, social life, work, housework and travel. The total score for all ten items can range from 0 to 50, zero points reflecting the poorest and 50 points showing the best functional performance in the daily live [4]. RMDQ is a self-report tool comprising 24 items designed to measure pain-related disability associated with low back pain. The questions address the patient's activity, pain, dependence on others, and emotional status. Items are scored either 0 (if left blank) or 1 (if endorsed), and the total RMDQ score is in the range between 0 (corresponding to "no disability") and 24 (reflecting "maximum disability") [4], [10].

Lumbar spine range of motion was assessed using Schober's test, which is performed with a tape measure held over the spine between the lumbosacral junction and 10 cm above it [12]. The intensity of pain was assessed with the Visual Analogue Scale (VAS), consisting of a 10 cm line, with two end points representing 0 ("no pain") and 10 ("pain as bad as it could possibly be"). The patient is instructed to rate their current level of pain by placing a mark on the line [12], [35].

2.6. Sample size

The target sample size of 60 participants was selected based on the value computed using a minimum sample size calculator. It was assumed in the calculations that 30 000–50 000 lumbar discectomy procedures are performed annually in Poland, and 80% power of the test was adopted in calculating the minimum sample size. An assumption of 80% was made, as this is the lowest accepted statistical power which, in the case of a low number of participants, allows for the results to be extrapolated to a wider population. With an assumed 15% drop-out rate during the initial examination and a predicted 20% rate of those who may not complete the programme, it was determined that 60 participants would be enrolled for the intervention. These assumptions are based on experience of other researchers [35].

2.7. Data analysis

The acquired data were subjected to statistical analyses computed using the software IBM SPSS 23. The distribution of the variables was calculated using the Kolmogorov–Smirnoff test ($n > 100$). Measures of location and dispersion were calculated depending on the agreement between the distribution of the variables and the theoretical distribution. The differences between the groups in the first measurement point were examined using the Mann–Whitney test, whereas the differences between the first and the second measurement were examined using Wilcoxon test. Effectiveness between groups was calculated using Student's *t*-test.

3. Results

3.1. Flow of included and patients' characteristics

146 patients were examined consecutively upon admission to the Neurosurgery Clinical Hospital. Sixty of these patients met the inclusion criteria. Out of the 86 patients who did not qualify for the program, 140 did not meet the inclusion criteria, and 6 refused to participate (Fig. 1). All eligible patients participated in therapy sessions and completed the program. No adverse medical events occurred during the program,

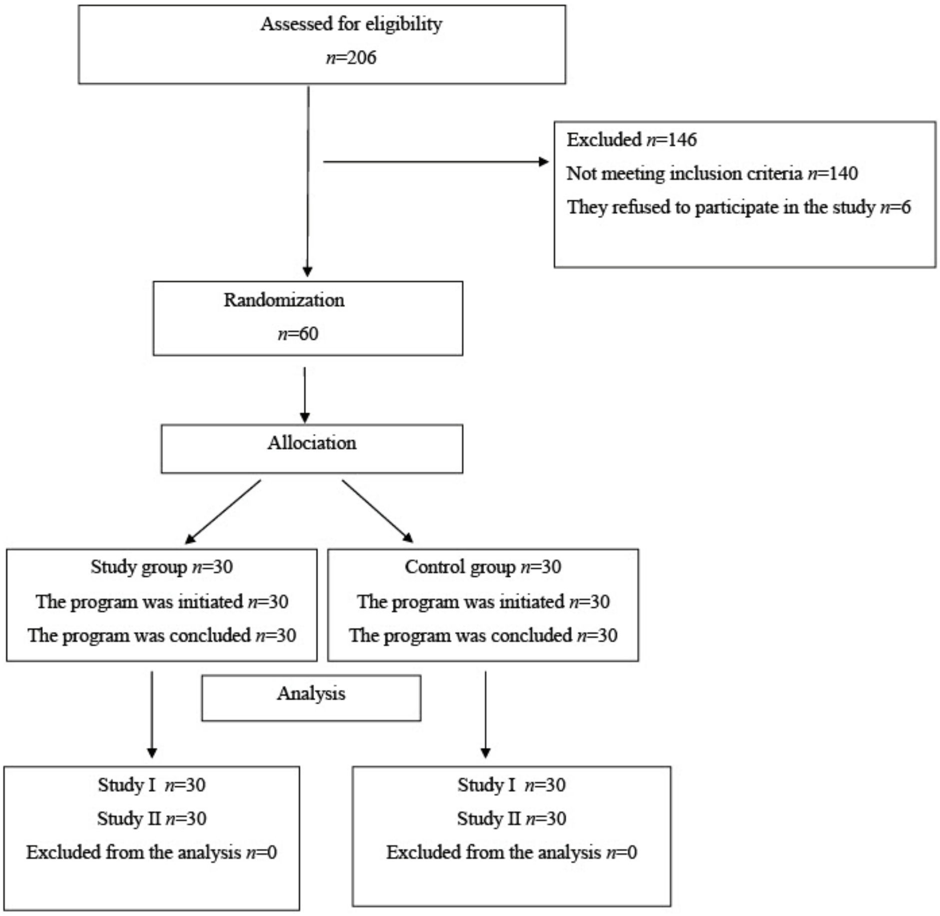

Fig. 1. Study flow chart

and all participants completed the final examination. Recruitment for the study began in January 2019 and lasted for six months.

Patients in the study group (n = 30) and the controls (n = 30) were matched for the demographic characteristics. The mean age of patients was 47 ± 15 years in the study group and 48 ± 14 years in the control group. Each group comprised 18 female and 12 male participants. In terms of anthropometrics (age, height, weight, BMI), there were no statistically significant differences between the groups. The characteristics of the study participants are shown in Table 1.

Table 1. Characteristics of study participants

Variable	Study group n = 30	Control group n = 30	Z	p
Age [years] X/SD	47/15	48/14	0.761	0.447
Body height [cm] X/SD	166/12	167/16	0.861	0.541
Body weight [kg] X/SD	62/4	64/3	0.653	0.365
BMI [kg/m^2] X/SD	26.3/13	25.8/9	0.871	0.531

X – mean, SD – standard deviation, Z – Mann–Whitney test, p – statistical significance.

3.2. Homogeneity of the patient groups (differences between the study group and the control group before the start of rehabilitation)

No statistically significant differences were found between the groups prior to the rehabilitation programme, in pain intensity reflected by VAS, functional status assessed with ODI and RMDQ, spine range of motion measured using Schober's test as well as most balance parameters ($p > 0.05$) (Table 2).

3.3. Results of the study group before and after rehabilitation

The statistical analysis showed significant decrease in the intensity of pain on VAS ($p < 0.01$), significant improvement in functional performance assessed with ODI ($p < 0.05$) and RMDQ ($p < 0.01$), and significantly increased spine range of motion in Schober's

Table 2. Results of the measurements of patients' capacities in the initial examination before the start of the rehabilitation programme in the study and the control group

Variable	Control group $n = 30$	Study group $n = 30$	Z	p
VAS [points] X/SD	6/3	6/3	0.398	0.691
ODI [points] X/SD	26/10	27/4	0.637	0.608
RMDQ [points] X/SD	12.9/1.78	14.01/2.1	0.1451	0.781
Schober's Test [cm] X/SD	11/2	12/1	2.116	0.1521
Area circular EO [cm^2] X/SD	2.89/1.9	2.91/2.18	0.33	0.76
Path length EO [cm] X/SD	120.6/21.8	129/22.9	1.67	0.07
Area circular EO [cm^2] X/SD	2.19/1.44	2.18/1.53	–0.02	0.982
Path length EO [cm] X/SD	33.41/9.03	33.36/8.97	–0.03	0.976
Area circular EC [cm^2] X/SD	3.90/2.11	2.67/1.67	–2.24	0.025
Path length EC [cm] X/SD	59.00/36.82	38.34/16.79	–2.01	0.044
Area circular EOSR [cm^2] X/SD	7.39/1.82	9.44/8.17	–0.56	0.574
Path length EOSR [cm] X/SD	99.98/33.40	99.23/23.99	0.98	0.326
Area circular EOSL [cm^2] X/SD	7.68/2.21	8.73/8.27	–0.09	0.929
Path length EOSL [cm] X/SD	96.22/28.86	88.27/27.43	–0.16	0.871
Area circular ECSR [cm^2] X/SD	7.59/3.02	7.47/1.18	0.98	0.329
Path length ECSR [cm] X/SD	111.03/27.82	111.92/32.14	–0.38	0.701
Area circular ECSL [cm^2] X/SD	7.10/1.58	7.15/1.87	0.23	0.819
Path length ECSL [cm] X/SD	89.61/26.21	89.61/15.09	1.06	0.290

X – mean, SD – standard deviation, VAS – Visual Analogue Scale, ODI – Oswestry Disability Index, RMDQ – Roland –Morris Disability Questionnaire, EO – Eyes Open, EC – Eyes Closed, EOSR – Eyes Open Right Leg, EOLL – Eyes Open Left Leg, ECRL – Eyes Closed Right Leg, ECLL – Eyes Closed Left Leg, Z – Mann–Whitney test, p – statistical significance.

Table 3. Results of the study group before and after rehabilitation

Variable	Study group before rehabilitation $n = 30$	Study group after rehabilitation $n = 30$	Z	p
VAS [points] X/SD	6/3	3/2	4.718	0.0041
ODI [points] X/SD	27/4	25/12	3.819	0.021
RMDQ [points] X/SD	14.01/2.1	11.4/1.8	4.781	0.00417
Schober's Test [cm] X/SD	12/1	14.4/2.1	4.991	0.01993

X – mean, SD – standard deviation, VAS – Visual Analogue Scale, ODI – Oswestry Disability Index, RMDQ – Roland –Morris Disability Questionnaire, Z – Wilcoxon test statistic, p – statistical significance.

test ($p < 0.05$), in the study group after rehabilitation (Table 3).

In the study group, statistically significant differences were observed between pre- and post-therapy measurements in most of the balance parameters evaluated ($p < 0.005$). The least significant differences in the results acquired before and after the therapy were found in the trials with Eyes closed, left leg; in this case statistically significant differences ($p < 0.005$) were only identified in the values Y average and Path length (Table 4).

3.4. Results of the control group before and after rehabilitation

The statistical analysis showed significant decrease in the intensity of pain on VAS ($p < 0.05$), significant improvement in functional performance assessed with ODI ($p < 0.05$) and RMDQ ($p < 0.05$), and significantly increased spine range of motion in Schober's test ($p < 0.05$) in the control group after rehabilitation (Table 5).

Table 4. Analytical results of balance measurement in the study group before and after rehabilitation

Study group		Before			After			Z	p
		Mean	Median	SD	Mean	Median	SD		
Eyes open, both legs	X average	–0.27	–0.45	1.20	–0.09	–0.05	1.05	1.35	0.176
	Y average	–3.41	–3.08	3.47	–2.36	–2.18	3.75	2.36	0.018
	Area circular	2.18	1.84	1.53	1.99	1.83	1.21	2.39	0.016
	Path length	33.36	33.80	8.97	31.98	31.12	8.65	3.35	0.001
	V average	1.21	1.19	0.34	1.18	1.18	0.24	2.27	0.023
Eyes closed, both legs	X average	0.58	–0.29	3.03	0.37	–0.29	2.95	1.36	0.173
	Y average	–2.69	–2.88	1.96	–2.05	–2.06	2.12	2.93	0.003
	Area circular	2.67	2.39	1.67	2.33	2.15	1.28	2.89	0.003
	Path length	38.34	40.31	16.79	36.92	38.33	16.41	4.19	<0.001
	V average	1.50	1.37	0.77	1.46	1.34	0.51	1.24	0.213
Eyes open, right leg	X average	5.85	7.13	3.15	5.30	6.56	2.85	4.01	<0.001
	Y average	–1.89	–1.22	4.07	–1.72	–1.21	3.89	1.98	0.046
	Area circular	7.39	6.90	1.82	7.06	6.78	1.79	2.93	0.003
	Path length	99.98	100.27	33.40	95.08	98.54	29.40	2.93	0.003
	V average	3.54	3.53	1.28	3.35	3.47	1.05	1.78	0.075
Eyes open, left leg	X average	–6.47	–7.39	3.23	–5.87	–6.17	2.83	3.34	0.001
	Y average	–2.16	–1.41	4.06	–1.88	–1.41	3.18	1.42	0.154
	Area circular	8.73	7.13	8.27	8.43	7.27	8.19	1.86	0.061
	Path length	88.27	94.77	27.43	82.51	89.39	23.46	3.82	<0.001
	V average	3.50	3.34	1.32	3.29	3.29	1.08	2.39	0.017
Eyes closed, right leg	X average	7.08	7.66	1.89	6.85	7.04	1.80	2.52	0.012
	Y average	–0.63	–0.62	1.32	–0.51	–0.62	1.06	1.99	0.046
	Area circular	7.47	6.88	1.18	7.26	6.74	1.05	2.36	0.017
	Path length	111.92	104.00	32.14	109.17	99.29	32.49	2.98	0.003
	V average	3.73	3.47	1.07	3.68	3.36	1.10	1.82	0.067
Eyes closed, left leg	X average	–6.16	–4.81	2.57	–5.84	–4.81	2.23	1.85	0.062
	Y average	–0.36	–2.32	2.91	–0.27	–2.06	2.83	1.99	0.046
	Area circular	7.15	8.13	1.87	7.03	7.77	1.64	1.82	0.068
	Path length	89.61	82.12	15.09	87.73	82.12	13.93	2.54	0.011
	V average	2.99	2.74	0.50	2.88	2.74	0.61	1.75	0.079

Z – Wilcoxon test statistic, SD – standard deviation, X average – average load point X which determined lateral coordinates X [cm], Y average – average load point Y which determined the anterior–posterior coordinates Y [cm], V average – average COP velocity [cm/s], p – significance level, $p < 0.05$ reflects statistically significant relationship, $p < 0.01$ reflects highly significant relationship, $p < 0.001$ reflects very highly significant relationship.

Table 5. Results of the control group before and after rehabilitation

Variable	Control group before rehabilitation $n = 30$	Control group after rehabilitation $n = 30$	Z	p
VAS [points] X/SD	6/3	4.7/1.2	3.814	0.0371
ODI [points] X/SD	26/10	23/12	1.861	0.041
RMDQ [points] X/SD	12.9/1.78	10.8/1.51	7.991	0.031
Schober's Test [cm] X/SD	11/2	13.6/1.8	6.113	0.0213

X – mean, SD – standard deviation, VAS – Visual Analogue Scale, ODI – Oswestry Disability Index, RMDQ – Roland–Morris Disability Questionnaire, Z – Wilcoxon test statistic, p – statistical significance.

In the control group, statistically significant differences were observed between pre- and post-therapy measurements only in a few balance parameters ($p <$ 0.005). Statistically significant differences between the results of measurements before and after the therapy were found in the trial with eyes closed and double-leg stance, where the differences were identified only in the values of *Y* average and Path length ($p < 0.005$). In the trials with eyes open and right leg stance, there was a difference in the value of Area circular, whereas in the trials with eyes open and left leg stance differences were found in the values of *Y* average, Path length and *V* average ($p < 0.005$). Corresponding results were observed in trials with eyes closed and left leg stance, in the parameters Path length and *V* average ($p < 0.005$) (Table 6).

Table 6. Analytical results of balance measurement in the control group before and after rehabilitation

Control group		Before			After			*Z*	*p*
		Mean	Median	SD	Mean	Median	SD		
Eyes open, both legs	*X* average	–0.17	–0.16	1.15	–0.22	–0.45	1.33	0.53	0.592
	Y average	–3.51	–3.19	3.42	–3.41	–3.08	3.47	1.1	0.273
	Area circular	2.19	1.84	1.44	2.18	1.84	1.53	0.1	0.916
	Path length	33.41	32.95	9.03	33.36	33.80	8.97	0.53	0.592
	V average	1.26	1.26	0.37	1.21	1.19	0.34	1.46	0.144
Eyes closed, both legs	*X* average	0.40	0.57	1.49	0.94	0.34	2.68	1.49	0.136
	Y average	–4.69	–4.32	5.25	–2.43	–2.72	2.95	2.06	0.039
	Area circular	3.90	3.45	2.11	3.57	3.03	2.08	1.34	0.179
	Path length	59.00	44.27	36.82	66.17	49.17	39.17	1.6	0.108
	V average	2.21	1.64	1.31	2.21	1.64	1.31	0	1
Eyes open, right leg	*X* average	3.99	2.75	19.96	4.05	2.75	19.91	0	1
	Y average	–1.22	–1.26	2.71	–0.95	–1.26	2.11	0	1
	Area circular	9.44	7.05	8.17	8.45	7.05	3.60	0	1
	Path length	99.23	97.58	23.99	116.39	108.28	35.30	2.59	0.009
	V average	3.62	3.55	0.94	3.86	3.68	1.20	1.6	0.108
Eyes open, left leg	*X* average	–6.52	–6.31	3.59	–4.95	–5.81	8.19	0	1
	Y average	–2.16	–1.67	4.07	–0.78	–0.67	3.21	2.1	0.036
	Area circular	7.68	7.05	2.21	12.61	7.45	18.70	1.82	0.067
	Path length	96.30	92.22	28.86	115.54	109.62	36.38	2.52	0.012
	V average	3.47	3.27	0.96	3.92	3.66	1.24	2.02	0.043
Eyes closed, right leg	*X* average	7.06	7.38	2.32	6.60	7.29	2.82	1.6	0.108
	Y average	–0.65	–1.17	2.43	–1.30	–0.62	3.31	0	1
	Area circular	7.59	6.78	3.02	7.69	6.78	2.90	0	1
	Path length	111.03	106.81	27.82	114.69	110.69	29.19	1.34	0.179
	V average	3.82	3.69	0.97	3.82	3.69	0.97	0	1
Eyes closed, left leg	*X* average	–6.80	–7.39	3.07	–6.80	–7.39	3.07	0	1
	Y average	–0.54	–0.46	2.49	–1.20	–0.95	3.41	1.34	0.179
	Area circular	7.10	6.93	1.58	8.98	7.58	8.00	1.6	0.109
	Path length	89.61	82.12	26.21	109.70	98.46	37.66	2.52	0.012
	V average	2.93	2.74	1.01	3.66	3.28	1.25	2.8	0.005

Z – Wilcoxon test statistic, SD – standard deviation, *X* average – average load point X which determined lateral coordinates *X* [cm], *Y* average – average load point Y which determined the anterior–posterior coordinates *Y* [cm], *V* average – average COP velocity [cm/s], *p* significance level, $p < 0.05$ reflects statistically significant relationship, $p < 0.01$ reflects highly significant relationship, $p < 0.001$ reflects very highly significant relationship.

Table 7. Differences in the results between the study group and the controls after completion of the rehabilitation programme

Variable	Effect of rehabilitation Control group $n = 30$	Effect of rehabilitation Study group $n = 30$	*T*	*p*
VAS [points] X/SD	1.3/1.8	3/1	4.522	0.0001
ODI [points] X/SD	1/1	4/3	5.196	0.0001
RMDQ [points] X/SD	2.1/1.51	2.59/0.3	1.743	0.0866
Schober's Test [cm] X/SD	2.6/0.2	2.4/2	–0.545	0.5878

X – mean, SD – standard deviation, VAS – Visual Analogue Scale, ODI – Oswestry Disability Index, RMDQ – Roland–Morris Disability Questionnaire, *T*-test – Student's *t*-test, *p* – statistical significance.

3.5. Differences between the study group and the controls after the conclusion of the rehabilitation

Statistical analysis showed significant differences in pain reduction on VAS in favour of the study group. Decrease in pain intensity was significantly more visible in the study group than in the controls (p = 0.0001). Likewise, improvement in functional performance reflected by ODI was significantly greater in the study group (p = 0.0001). On the other hand, no statistically significant differences were observed in the participants' functional status measured with RMDQ (p = 0.0866) or in spine range of motion in Schober's test (p = 0.5878) between the groups (Table 7).

Similarly, significantly greater improvements in balance parameters were found in the study group (p < 0.05). Statistically significant differences between the study group and the controls after the therapy were identified in the trial with eyes closed, double-leg stance, in the parameters of Area circular, Path length and mean velocity (V average), in trials with eyes open, left leg stance, in Path length, and in trials with eyes closed, left leg stance, in Path length and mean velocity, with significance level reflected by p < 0.005 (Table 8).

Table 8. Differences in the balance parameters between the study group and the controls after completion of the rehabilitation programme

After		Study group			Control group			Z	p
		Mean	Median	SD	Mean	Median	SD		
Eyes open, both legs	X average	–0.09	–0.05	1.05	–0.22	–0.45	1.33	0.50	0.615
	Y average	–2.36	–2.18	3.75	–3.41	–3.08	3.47	1.58	0.114
	Area circular	1.99	1.83	1.21	2.18	1.84	1.53	–0.37	0.712
	Path length	31.98	31.12	8.65	33.36	33.80	8.97	–0.87	0.383
	V average	1.18	1.18	0.24	1.21	1.19	0.34	–0.81	0.416
Eyes closed, both legs	X average	0.37	–0.29	2.95	0.94	0.34	2.68	–1.08	0.280
	Y average	–2.05	–2.06	2.12	–2.43	–2.72	2.95	0.72	0.473
	Area circular	2.33	2.15	1.28	3.57	3.03	2.08	–2.36	0.018
	Path length	36.92	38.33	16.41	66.17	49.17	39.17	–3.19	0.001
	V average	1.46	1.34	0.51	2.21	1.64	1.31	–2.43	0.015
Eyes open, right leg	X average	5.30	6.56	2.85	4.05	2.75	19.91	1.54	0.124
	Y average	–1.72	–1.21	3.89	–0.95	–1.26	2.11	0.01	0.994
	Area circular	7.06	6.78	1.79	8.45	7.05	3.60	–1.25	0.212
	Path length	95.08	98.54	29.40	116.39	108.28	35.30	–1.84	0.066
	V average	3.35	3.47	1.05	3.86	3.68	1.20	–1.12	0.261
Eyes open, left leg	X average	–5.87	–6.17	2.83	–4.95	–5.81	8.19	0.22	0.824
	Y average	–1.88	–1.41	3.18	–0.78	–0.67	3.21	–1.30	0.193
	Area circular	8.43	7.27	8.19	12.61	7.45	18.70	–1.18	0.237
	Path length	82.51	89.39	23.46	115.54	109.62	36.38	–3.39	0.001
	V average	3.29	3.29	1.08	3.92	3.66	1.24	–1.69	0.090
Eyes closed, right leg	X average	6.85	7.04	1.80	6.60	7.29	2.82	–0.18	0.853
	Y average	–0.51	–0.62	1.06	–1.30	–0.62	3.31	0.49	0.626
	Area circular	7.26	6.74	1.05	7.69	6.78	2.90	0.47	0.636
	Path length	109.17	99.29	32.49	114.69	110.69	29.19	–1.06	0.290
	V average	3.68	3.36	1.10	3.82	3.69	0.97	–0.98	0.326
Eyes closed, left leg	X average	–5.84	–4.81	2.23	–6.80	–7.39	3.07	1.47	0.141
	Y average	–0.27	–2.06	2.83	–1.20	–0.95	3.41	0.78	0.433
	Area circular	7.03	7.77	1.64	8.98	7.58	8.00	–0.93	0.352
	Path length	87.73	82.12	13.93	109.70	98.46	37.66	–2.67	0.008
	V average	2.88	2.74	0.61	3.66	3.28	1.25	–2.92	0.004

Z – Mann–Whitney test, SD – standard deviation, X average – average load point X which determined lateral coordinates X [cm], Y average – average load point Y which determined the anterior–posterior coordinates Y [cm], V average – average COP velocity [cm/s], p significance level, p < 0.05 reflects statistically significant relationship, p < 0.01 reflects highly significant relationship, p < 0.001 reflects very highly significant relationship.

4. Discussion

The current study was a response to the need for a clearly defined and evidence-based postoperative rehabilitation programme, and it was designed to assess the change in psychophysical performance of patients after lumbar discectomy in relation to the postoperative therapy. In the literature related to these issues, there are a number of studies investigating a variety of rehabilitation programmes after lumbar discectomy. These programmes vary in terms of the timing of postoperative interventions introducing kinesitherapy, the type of exercises applied, as well as their intensity and frequency [1], [2], [6], [9], [11], [14], [26], [27], [32]. However, it is difficult to compare the effectiveness of such widely varied programmes. Consequently, it is difficult to choose the best one for use in clinical practice while, as it is well known, there is a need to enhance the outcome of discectomy with postoperative rehabilitation [8], [16], [36]. Nevertheless, many patients receive little or no formal rehabilitation after surgery [36].

The study confirmed the effectiveness of the investigated rehabilitation protocol in both groups in relation to all parameters analysed, with the exception of static balance, where the gains were significantly greater in the study group. In this group, significant improvements were observed in almost all balance parameters. By comparison, in the control group the findings showed significant improvements only in the mean values of Y average and Path length in trials with eyes closed and double-leg stance, in the parameter of Area circular in trials with eyes open and right leg stance, and in Y average, Path length and V average in trials with eyes open and left leg stance. Corresponding results were observed in trials Eyes closed and left leg stance, in the parameters Path length and V average. Similar results were reported by Ozkara et al. [29], who showed that rehabilitation of patients after lumbar discectomy reduces pain, improves functional ability and lumbar spine range of motion. There is also contradictory evidence regarding effectiveness of postoperative rehabilitation, for instance contributed by Oosterhuis et al. [9], who conducted a randomised multicentre trial assessing effects of early rehabilitation (exercise therapy) after lumbar disc surgery, and reported no effects of such intervention. The control group in that study comprised patients after the surgery who were not referred to postoperative rehabilitation. The parameters investigated in the study included ODI, back pain and leg pain measured on VAS, as well as recovery level rated on a Likert scale and general physical and mental health evaluated with SF12, all of these were assessed 3, 6, 9, 12 and 24 months after the surgery [9]. In 2014, Oosterhuis et al. [38] conducted a systematic review of the literature related to the effectiveness of clinical rehabilitation after lumbar discectomy. The authors identified 22 clinical trials, involving a total of 2503 patients. The authors posed the following research questions of whether active rehabilitation after the surgery is more effective than no treatment as well as which type of active rehabilitation is most effective. They also assessed effectiveness of interventions relative to when postoperative rehabilitation is initiated. In their overall conclusion, the authors stated that none of the studies demonstrated high or even moderate strength of scientific evidence. All the interventions in their design varied considerably in terms of their content, duration and intensity [20]. In fact, these conclusions provided a motivation for the current study where the patients were randomly divided into two groups, the control group participating in the basic version of the rehabilitation programme and the study group, in addition to the same programme, receiving manual therapy.

The present study shows that the rehabilitation protocol additionally including manual therapy was more effective than the basic programme without manual therapy. Its superiority was reflected by more pronounced decrease in pain intensity, more visibly improved functional performance as well as improved static balance. It is possible that one of the mechanisms responsible for improvements in the aforementioned functions is associated with the fact that the techniques used in manual therapy, such as fascial manipulation, beneficially affect the structure of soft tissues. Muscle and joint contractures that develop in connection to discogenic pain, especially the accompanying radiculopathy, can lead to restricted mobility of the lumbar spine and to impaired static balance [3], [15]. Radicular pain can also be associated with the epidural and muscle scarring which develops after any spinal surgery, including discectomy. Therefore, personalised work with each patient, supplemented with well-matched manual therapy and patient education regarding physical activity after the surgery, speeds up the process of recovery [25].

Comparison of the present findings with other results reported in the literature, and generally attempts to compare studies assessing different postoperative rehabilitation protocols, encounter difficulties due to the diverse methodical approaches applied in the scientific research and because of the diversity of the rehabilitation protocols investigated [25]. There are many undefined factors to be considered in the planning of postoperative rehabilitation, such as the type of the intervention or timing (the time point to introduce post-surgery rehabilitation or its duration), whereas the current findings demonstrate the effectiveness of the rehabilitation protocol applied in this group of patients, which is the practical value of our research. The present study provides evidence confirming beneficial effects of the clearly formulated postoperative rehabilitation programme on the psychophysical performance of patients after lumbar discectomy and shows that the rehabilitation protocol can justifiably be implemented in the daily practice.

Practical implications

Techniques of manual therapy applied in addition to the traditional model of postoperative treatment after discectomy have been shown to be more effective in reducing pain, increasing balance and reducing disability.

Limitations

The present study has some limitations. Firstly, in our study, patients did not receive any pre-rehabilitation. This is due to the fact that in Poland few, if any, patients have any rehabilitation plan prior to discectomy. This may be an important factor, given that research has shown positive effects of pre-rehabilitation, e.g., after hip or knee replacement surgeries in the patients' functional performance at 6 months after the surgery [21]. Therefore, it seems that further research on the effectiveness of different types of therapy should also address rehabilitation applied before the surgery. The study also did not include a follow-up evaluation to assess the lasting effects of the postoperative rehabilitation. Therefore, it seems the results of the study generated new questions about the long-term effects of postoperative rehabilitation and thus suggest further directions and subject matter for further research focusing on rehabilitation after disc surgery.

5. Conclusions

The study showed that the postoperative rehabilitation programmes produced a positive and statistically significant effect in both groups of participants, reflected by improvements in most of the psychophysical parameters investigated, except for balance in the control group. It was shown that the protocol additionally including manual therapy was more effective than the basic programme. Its superiority was reflected by greater pain reduction, more visibly improved functional performance as well as improved static balance. The results of the study are of practical importance, as the protocols tested can be implemented in daily clinical practice in postoperative rehabilitation offered to patients after lumbar discectomy.

Conflicts of interests

The authors declare that they have no competing interests.

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