

EFFECT OF ELECTROMYOSTIMULATION ON ABDOMINAL WALL MUSCLE ACTIVITY AND STRENGTH AFTER SEPARATION HERNIOPLASTY (COMPONENT SEPARATION TECHNIQUE)

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High prevalence of postoperative ventral hernias necessitates the development of effective rehabilitation protocols to restore abdominal muscle function early and reduce recurrence risk. This study aimed to evaluate the effects of electromyostimulation (EMS) of the anterior abdominal wall muscles on physical activity levels and strength performance in patients after surgical treatment for postoperative ventral hernias. We enrolled 128 patients (mean age, 47.9 ± 8.6 years) who underwent open combined component separation surgery with retromuscular mesh implantation. In the treatment group ($n = 64$), the course of anterior abdominal wall EMS (enabled by COMPEX SP-2.0) started on the 10th day after surgery; in the control group ($n = 64$), we followed a standard post-surgery protocol. The assessed indicators were the level of physical activity (pedometry, 7 days) and the strength of the trunk muscles (strain dynamometry, registered with a BackCheck 700 device). Six months after surgery, the EMS group showed significantly greater muscle strength gains than the control group: in trunk extension, median strength was 26.9 kg versus 15.4 kg (74.7% increase; $p < 0.001$); in flexion, it was 15.7 kg versus 8.0 kg (96.3% increase; $p < 0.001$). The level of physical activity in the EMS group was significantly higher: the median number of steps per week was 27304.5 ± 2903.48 (95% CI 20964.6–33644.5), while in the control group it reached 11173.6 ± 3688.8 (95% CI 10065.4–12281.9) steps. This indicates a recovery to 90.0% of the preoperative level. Thus, an early post-surgery course of EMS of the anterior abdominal wall muscles is an effective rehabilitation method that significantly improves the strength characteristics of the core muscles and restores the levels of physical activity in patients.

Keywords: electromyostimulation, postoperative rehabilitation, ventral hernias, hernioplasty, component separation technique, myostimulation

Author contribution: Demin NA — study design, data collection, text authoring; Achkasov EE — research supervision, expert control, editing; Polyayev BA — expert control, editing; Shishkin AA — statistical data processing; Medvedeva AI — clinical data collection, text authoring; Ostanin OE — clinical data collection, statistical processing.

Compliance with ethical standards: the study was approved by the Ethics Committee of the Sechenov Moscow State Medical University of the Ministry of Health of the Russian Federation (Minutes No. 08-19 of June 05, 2019), and conducted in accordance with the 2013 Declaration of Helsinki. All patients signed a voluntary informed consent to participate in the study.

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ВЛИЯНИЕ ЭЛЕКТРОМИОСТИМУЛЯЦИИ НА ФИЗИЧЕСКУЮ АКТИВНОСТЬ И СИЛУ МЫШЦ БРЮШНОЙ СТЕНКИ БОЛЬНЫХ ПОСЛЕ СЕПАРАЦИОННОЙ ГЕРНИОПЛАСТИКИ

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В связи с высокой распространенностью послеоперационных вентральных грыж необходима разработка эффективных протоколов реабилитации, направленных на раннее восстановление функции мышц брюшного пресса и снижение риска рецидива. Целью работы было оценить влияние электромиостимуляции (ЭМС) мышц передней брюшной стенки на уровень физической активности и силовые показатели у пациентов после хирургического лечения послеоперационных вентральных грыж. В исследовании участвовало 128 пациентов (47,9 ± 8,6 лет), перенесших открытую комбинированную сепарационную герниопластику с ретромускулярной установкой сетчатого имплантата. Пациентам в основной группе ($n = 64$) с 10-х суток после операции проводили курс ЭМС передней брюшной стенки аппаратом COMPEX SP-2.0, в контрольной ($n = 64$) — стандартные послеоперационные мероприятия. Оценивали уровень физической активности (шагометрия за 7 суток) и силу мышц туловища (тензодинамометрия, Back-Check 700). Через 6 месяцев после операции в группе ЭМС зафиксировано значимое увеличение силы мышц: при разгибании туловища медиана силы составила 26,9 кг против 15,4 кг в контроле (прирост на 74,7%; $p < 0,001$); при сгибании — 15,7 кг против 8,0 кг в контроле (прирост на 96,3%; $p < 0,001$). Уровень физической активности в группе ЭМС был статистически значимо выше: медиана числа шагов за неделю — 27304,5 ± 2903,48 (95% ДИ 20964,6–33644,5) в контрольной группе — 11173,6 ± 3688,8 (95% ДИ 10065,4–12281,9) шагов, что соответствует восстановлению до 90,0% от исходного дооперационного уровня. Таким образом, курс ЭМС мышц передней брюшной стенки, начатый в ранние сроки после герниопластики, является эффективным методом реабилитации, достоверно улучшающим силовые характеристики мышц кора и восстанавливающим физическую активность пациентов.

Ключевые слова: электромиостимуляция, послеоперационная реабилитация, вентральные грыжи, герниопластика, миостимуляция

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Despite the continued improvement of techniques, surgical treatment of postoperative ventral hernias (PVH) remains a challenge [1]. The key factor behind the high risk of recurrence and impaired functional integrity of the anterior abdominal wall is postoperative muscle dysfunction [2]. The formation of a hernia defect and subsequent surgery inevitably damage neuromuscular structures, impair proprioception, cause atrophy, and weaken the core musculature, ultimately reducing muscle strength and endurance [3].

Restoring the functional viability of muscles is the central task of rehabilitation [4]. Traditionally, it is achieved through physical therapy, but pain and risk of complications often limit its initiation early in the rehabilitation period [5]. For this reason, methods specifically designed for the early post-surgery period are especially relevant. Among them, electromyostimulation (EMS) of the anterior abdominal wall muscles shows the most promise [6, 7].

EMS enables targeted muscle activation, improves their trophism, prevents atrophy, and maintains muscle tone when it is still difficult for the patient to move actively [6]. Thus, studying the effectiveness of various physiotherapy methods, particularly postoperative hardware-based myostimulation, is crucial for advancing the muscle function restoration regimens [8]. The respective efforts will add to the development of scientifically based rehabilitation protocols aimed at reducing recovery time, improving the quality of life of patients, and reducing the frequency of PVH relapses.

This study aimed to investigate the effects of electromyostimulation (EMS) of the anterior abdominal wall muscles on physical activity levels and strength performance in patients after surgical treatment for postoperative ventral hernias.

METHODS

This prospective pilot clinical trial was conducted at V.V. Vorokhov City Clinical Hospital No. 67, Moscow Department of Health, from 2019 to 2024. It included 128 patients aged 28–83 years (mean: 47.9 ± 8.6 years) who underwent surgery for PVH (mean hernial defect size: 150.4 ± 38.1 cm²; range: 103.0–351.3 cm²). The technique was an open combined separation hernioplasty with implantation of a 15.0 × 15.0 cm polypropylene mesh in the retromuscular space.

The inclusion criteria were: stability of the implanted retinal prosthesis; no early postoperative complications (including infection of the surgical wound, formation of hematomas, thrombotic events, pulmonary infection, recurrence of proliferative vitreoretinopathy, etc.); availability of a signed informed voluntary consent form; technical capability and readiness to interact with the researchers remotely on a regular basis; body mass index below 39.9 kg/m²; absence of decompensated diabetes mellitus, as well as chronic pathologies of the respiratory and cardiovascular systems; absence of diseases of the musculoskeletal system that limit physical activity; absence of malignant neoplasms.

The exclusion criteria were: relapsing PVH; severe somatic pathology in the decompensation stage; acute infectious

processes; a history of epilepsy or an implanted electronic device (pacemaker, defibrillator); pregnancy and lactation; patient's refusal to participate in a rehabilitation program.

After surgery, patients were randomly assigned to two comparable groups using a random number table. The groups were similar in terms of gender, age, body mass index, and baseline hernia characteristics. In the control group (group I, $n = 64$), patients underwent standard postoperative treatment, which, in addition to drug therapy, included early physical activation, breathing exercises, and dynamic monitoring without additional physiotherapy. In the treatment group (group II, $n = 64$), patients received a course of anterior abdominal wall EMS procedures in addition to standard postoperative management.

The groups were comparable in age, body mass index, and age group distribution ($p > 0.05$ for all comparisons), which confirms the correctness of the randomization and eliminates the influence of these factors on the results of the study (Table).

Because of the need to complete early postoperative protocols and minimize the risk of local inflammatory complications, we started the EMS course in the treatment group on day 10 after hernioplasty. The device used for this purpose was the COMPEX SP-2.0 (Compex Medical, Switzerland), a certified multichannel myostimulator. The procedures were performed by qualified physiotherapists in a dressing room. Adhesive electrodes were placed on the skin over the middle third of the rectus abdominis and oblique abdominal muscles on both sides.

The stimulation parameters followed evidence-based guidelines and the device manufacturer's recommendations for rehabilitation programs: strengthening mode; pulse frequency, 50–70 Hz; pulse duration, 300–400 μs; inter-pulse series pause, 10 seconds; ramp-up time, 2 seconds; and ramp-down time, 1 second. The current strength was adjusted individually for each patient to achieve visible signs of pronounced, painless muscle contraction. Initially, the duration of one procedure was 5 minutes, and by the end of the first week of therapy it was gradually increased to 10 minutes. The course included 12 procedures: 3 sessions per week (1 session every 2 days) over 4 weeks.

The main method for assessing anterior abdominal wall muscle strength was strain dynamometry (SDM), performed twice: preoperatively and on postoperative days 38 and 40 (after completing the full rehabilitation course in both groups). BackCheck 700 (Dr.Wolff GmbH, Germany), a computerized dynamometer system, was used for measurements. The tests were performed under standardized conditions: the patient stood on the system's platform with feet at shoulder width and the pelvis and hips fixed to stabilize the position. For the local abdominal muscle strength test, patients flexed their trunk forward for 3–5 seconds, maximum effort, against resistance from a measuring lever placed at sternum level. For the trunk extension strength test, the lever was positioned against the lower thoracic region of the patients' backs, who then leaned back at maximum effort. The minimum rest period between the attempts was 30 seconds. Two or three successful attempts were made in each direction, and the system recorded the maximum force in kilograms, displaying flexor and extensor

Table. Baseline characteristics of patients in the study groups

Indicators	Group		<i>p</i>
	Group I	Group II	
Age (years), M (SD)	44.0 (10.5)	45.7 (11.9)	0.429
Age groups, M (SD)	2.56 (1.10)	2.53 (1.16)	0.904
BMI, M (SD)	29.32 (3.11)	30.63 (4.29)	0.074

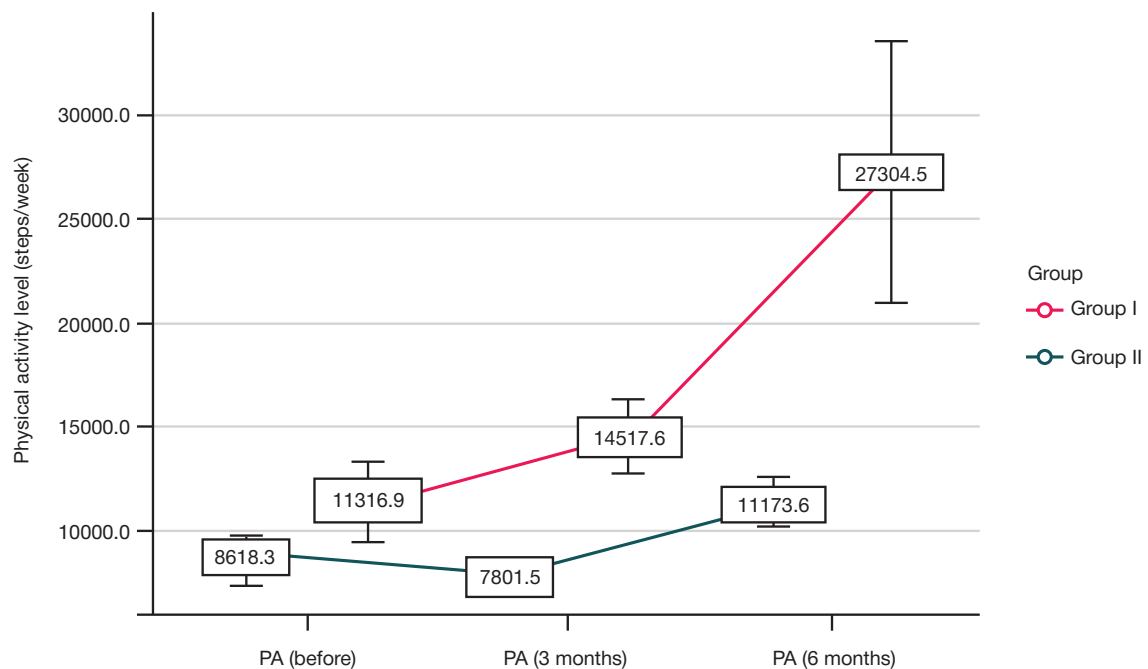


Fig. 1. Dynamics of physical activity in the study groups

indicators separately. The best result was used for the subsequent analysis.

The level of physical activity (PA) of the patients was assessed by the number of steps completed in 7 days, which were registered before the EMS course began, and at 3 and 6 months after its completion using a wrist pedometer. Thus, we quantified the dynamics of recovery of patients' daily activity levels in the postoperative period.

Statistical processing of the obtained data was performed in StatTech 2.8.0 (Stattech, Russia) for Windows 11® (Microsoft, USA). The normality of distribution of the quantitative data was assessed with the help of the Shapiro-Wilk test. To compare independent samples, we used Student's *t*-test for parametric data and Mann-Whitney *U*-test for nonparametric data. To compare the indicators before and after treatment within the groups, we applied the paired *t*-test or the Wilcoxon test. Qualitative features were compared using the chi-square test (χ^2). The differences were considered statistically significant at $p < 0.05$.

RESULTS

The analysis of the pre-surgery PA data revealed intergroup significant differences ($p = 0.049$) confirmed by Student's *t*-test: in group I, the mean PA level was 8618.3 ± 4057.8 (95% CI 7399.2–9837.4), and in group II it was 11316.9 ± 8588.8 (95% CI 9441.5–13192.3). The analysis of data collected 3 months after surgery, using Welch's *t*-test, also revealed significant between-group differences ($p < 0.001$): in group I, the mean PA level was 7801.5 ± 1969.2 (95% CI 7209.9–8393.1), in group II — 14517.6 ± 8070.8 (95% CI 12755.3–16279.9). Significant differences were recorded after 6 months, too ($p < 0.001$, Welch's *t*-test): in group I, the figure was 11173.6 ± 3688.8 (95% CI 10065.4–12281.9), and in group II — 27304.5 ± 2903.8 (95% CI 20964.6–33644.5). An intragroup analysis, which used the Fisher's exact test and repeated measurements, demonstrated significant dynamics in the level of physical activity in both groups ($p < 0.001$). In group I, the studied indicator increased significantly between months 3 and 6 ($p < 0.001$); in group II, however, the improvement was

already evident by the third month after surgery ($p < 0.001$) and persisted through month 6 ($p < 0.001$), suggesting that EMS induced earlier and more effective recovery (Figure 1).

The analysis of SDM data from the trunk extension test also confirmed the effectiveness of EMS. The comparison of the groups before the intervention using the Mann-Whitney *U* test showed no significant differences (group I: Me = 12.9, Q_1 – Q_3 = 8.1–18.4; group II: Me = 10.7, Q_1 – Q_3 = 6.9–17.3; $p = 0.215$). Six months after surgery, a similar comparison revealed significantly higher indicators in the EMS group (group I: Me = 15.4, Q_1 – Q_3 = 10.7–20.8; group II: Me = 26.9, Q_1 – Q_3 = 19.4–32.7; $p < 0.001$). To assess intragroup perioperative changes, we applied the Wilcoxon test, which confirmed significant improvements in both groups ($p < 0.001$). However, the absolute growth of extension force was significantly higher in group II (Fig. 2).

Pre-treatment analysis of the flexion force of the trunk using the Mann-Whitney *U* test revealed significant differences between groups (group I: Me = 4.9, Q_1 – Q_3 = 3.1–6.3; group II: Me = 3.8, Q_1 – Q_3 = 2.2–5.2; $p = 0.041$). After 6 months of treatment, a similarly set up comparison showed that the gap between the groups not only persisted but increased significantly (group I: Me = 8.0, Q_1 – Q_3 = 5.5–12.0; group II: Me = 15.7, Q_1 – Q_3 = 11.9–20.0; $p < 0.001$). Intragroup analysis using the Wilcoxon test confirmed significant positive dynamics in each group ($p < 0.001$). However, the final results in group I were more than twice as high as in group II (Fig. 3).

DISCUSSION

The study demonstrates that EMS of the anterior abdominal wall muscles after hernioplasty for postoperative ventral hernias significantly and clinically improves both physical activity levels and muscle strength.

The results obtained strongly indicate the effectiveness of this method as one of the components of early rehabilitation. The analysis of the dynamics of PA levels revealed that, despite the initial intergroup differences, by the 3rd and 6th months post-surgery, the number of steps made in a week was significantly higher in the EMS group ($p < 0.001$). This result

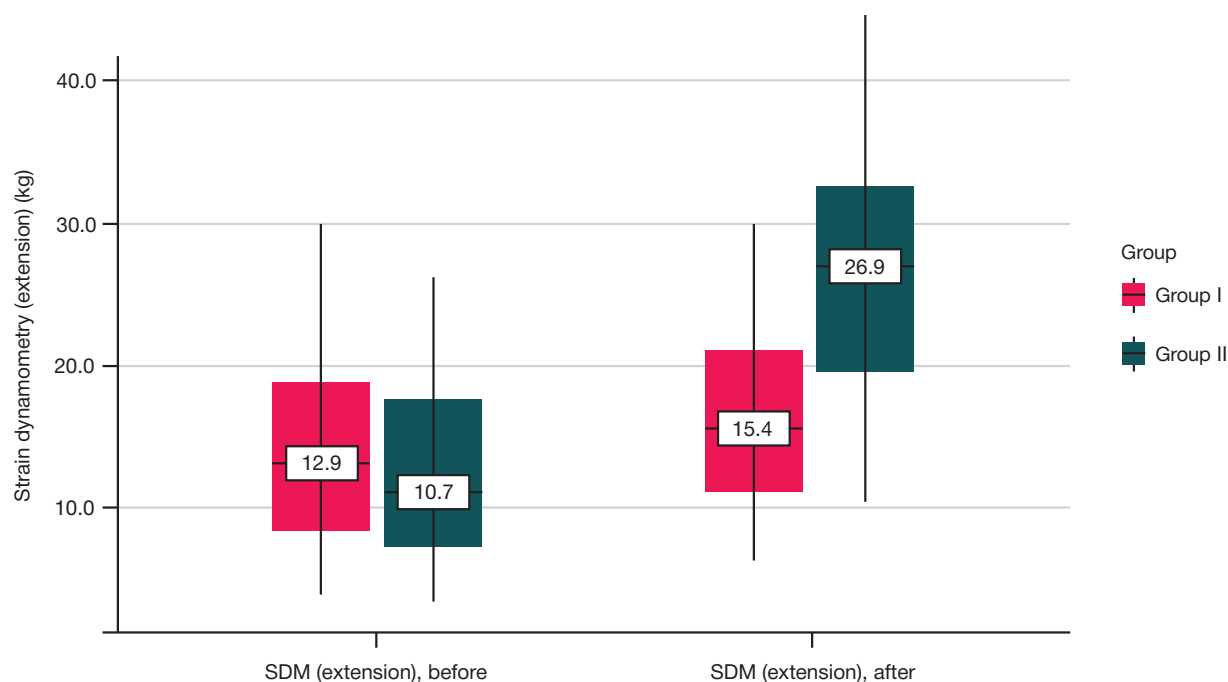


Fig. 2. Dynamics of trunk extension strength according to tensodynamometry

can be explained by the fact that targeted strengthening of the abdominal muscles through exercise and postoperative EMS creates a more stable and functional muscular corset, which may reduce discomfort during movement.

Analysis of the SDM data provided the most convincing evidence of the effectiveness of EMS. In the trunk extension test 6 months after surgery, the median strength index in the EMS group (26.9 kg) was 74.7% higher than in the control group (15.4 kg; $p < 0.001$). Even more pronounced differences were recorded in the trunk flexion test, which specifically evaluates the function of the rectus and oblique abdominal muscles. Initially, the EMS group had a small but statistically significant advantage: 3.8 kg versus 4.9 kg ($p = 0.041$). By the end of the observation period, however, the gap between the groups had widened substantially: the median flexion force in group I (15.7 kg)

was nearly twice that of the control group (8.0 kg). Such a significant increase in flexion strength is a direct consequence of the technique used, which helped prevent postoperative muscular atrophy and stimulated neuromuscular adaptation.

Our clinical data are consistent with the results of an earlier experimental animal study (mini-pigs), which demonstrated the safety and effectiveness of applying EMS to the anterior abdominal wall muscles after retro-rectus hernioplasty [7]. It was established that starting EMS on postoperative day 30 improves capillarization of muscle tissue and promotes more complete formation of the connective tissue capsule around the mesh implant. We took these findings into account when timing the start of the EMS course in this clinical trial (from day 10). They also help explain the marked increase in muscle strength and physical activity in the EMS group by 3 and 6 months after surgery.

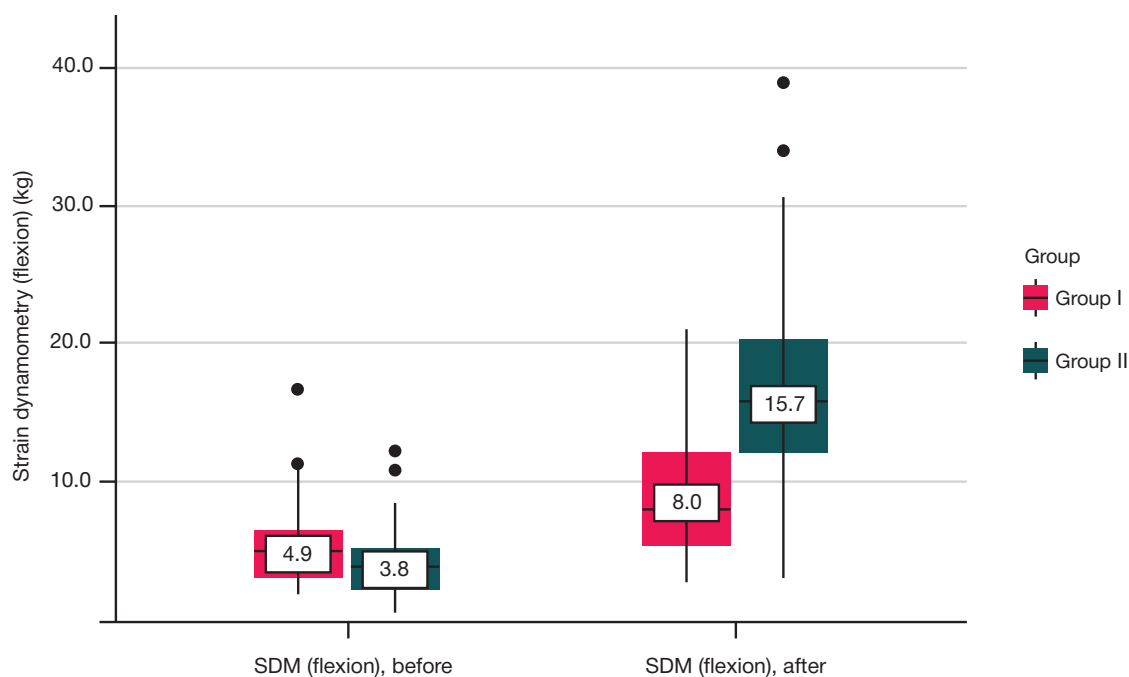


Fig. 3. Dynamics of trunk flexion strength according to tensodynamometry

The Russian literature also emphasizes the importance of comprehensive physical rehabilitation after hernioplasty. For example, it has been reported that starting physical therapy early helps reduce postoperative complications, speeds up the recovery of the functional state of the anterior abdominal wall muscles, and helps prevent recurrence [9]. In an earlier study, researchers recommended starting electromyostimulation one month after surgery in 10- to 15-procedure courses and noted its positive effects on microcirculation and muscle tissue trophism without increasing intra-abdominal pressure [10]. Our protocol, which recommends starting EMS on day 10, incorporates these recommendations and our own experimental data and ultimately enables a faster, more pronounced increase in muscle strength and physical activity.

Current research confirms the effectiveness of physiotherapy methods in correcting postoperative muscle tone disorders. Compared with standard drug treatment, complex physiotherapy — which included physical exercises, magnetic therapy, percutaneous electrical stimulation, and postisometric relaxation — reduced pathological muscle tone by 56.3% and increased range of motion by 58.7% after abdominal and thoracic surgery [11]. Our study focused on targeted application of EMS to the anterior abdominal wall muscles, but its results also demonstrate a significant improvement in strength and physical activity, which is consistent with the general principle of the positive effect of physiotherapy on functional recovery after abdominal surgery.

There are various instrumental tests that enable an objective assessment of the functional state of the abdominal wall muscles. Electromyography (EMG) is considered the most informative. In clinical practice, EMG is still more of an experimental diagnostic method; it is not included in the list of mandatory pre-hernioplasty tests [12]. We measured muscle

strength using strain dynamometry, a method that allows quantifying the maximum isometric force. Combined with pedometry, it gives a comprehensive picture of the recovery of abdominal function and physical activity of the patient. In addition, the cited review presents data supporting the beneficial effect of electromyostimulation on the restoration of muscle electrical activity in the postoperative period, which is consistent with our results showing a faster and more pronounced increase in muscle strength and physical activity in the EMS group.

Based on the above, the electromyostimulation course started on postoperative day 10 showed pronounced rehabilitation potential by significantly improving key functional outcomes in patients after retromuscular hernioplasty. Our results are consistent with data from both experimental and clinical studies confirming the effectiveness of physiotherapy methods in postoperative rehabilitation of abdominal patients. Further research should focus on optimizing EMS protocols, assessing long-term outcomes and patients' quality of life, and exploring the combination of EMS with other rehabilitation techniques.

CONCLUSIONS

Electromyostimulation of the anterior abdominal wall muscles, initiated on postoperative day 10 after separation hernioplasty, significantly improves muscle strength (74.7%–96.3%) and accelerates the recovery of physical activity in patients. This method is an effective and physiologically sound component of complex postoperative rehabilitation in the surgical treatment of ventral hernias. Further studies are needed to confirm the effect of EMS on long-term functional outcomes and the risk of recurrence.

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