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DIGEST AND REVIEWS

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Expenditure of early initiation of neuromuscle electrical stimulation after orthopedic surgeries on the hip and knee joints (literature review)

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Every year the number of cases of anterior cruciate ligament reconstruction, total hip and knee arthroplasty increases. This leads to the improvement of rehabilitation protocols for patients after surgery to quickly restore normal range of motion and return to normal life. Objective. Provide physical therapists with an evidence-based resource that can guide clinical decision making, thereby enabling clinicians to make effective use of electrical stimulation to improve muscle function in patients after orthopedic operations and increase awareness of the range of applications for neuromuscular electrical stimulation (NMES). Metods. Electronic databases PMC, PUBMED and SCOPUS were used to search the relevant literature, which was published in the period from the creation of databases to December 2020. Additional articles were identified by analyzing bibliographies in systematic reviews. We have reviewed the full text of selected articles to confirm that all included studies meet the stated objectives of the review. Results. In patients after orthopedic surgery on the hip and knee joints, the inclusion of NMES in standard physical therapy significantly increases the strength of the quadriceps muscle compared to conventional physical therapy. Early activation can be helpful to avoid suppression of quadriceps function and atrophy, provide the patient with the most effective course of rehabilitation, and return to active life after anterior cruciate ligament reconstruction or knee arthroplasty. It is also advisable to use NMES as an alternative mechanical prevention of deep vein thrombosis and edema in the early period after hip arthroplasty. In the presented studies, patients tolerated NMES well even when it initiated on 1–2 postoperative days. However, no standardized NMES protocols reported in the literature, so the choice of stimulation parameters is at the discretion of the physician and usually depends on the individual tolerability of the patients. Key words. Neuromuscular electrical stimulation, anterior cruciate ligament reconstruction, arthroplasty, hip joint, knee joint.

Щорічне збільшення випадків виконання операцій реконструкції передньої схрещеної зв'язки, тотального ендопротезування кульшового та колінного суглобів обумовлює вдосконалення протоколів реабілітації пацієнтів після хірургічного втручання для швидшого відновлення нормального обсягу рухів і повернення до звичного способу життя. Мета. Надання доказового ресурсу, який може дозволити клініцистам ефективно використовувати електричну стимуляцію для поліпшення функції м'язів у пацієнтів після ортопедичних операцій і збільшити обізнаність щодо сфери застосувань нейром'язової електричної стимуляції (НМЕС). Методи. Електронні бази даних PMC, PUBMED і SCOPUS застосовано для пошуку відповідної літератури, яка була опублікована в період від створення баз до грудня 2020 року. Додаткові статті виявлено шляхом аналізу бібліографій у систематичних оглядах. Переглянуто повні тексти обраних статей, щоб підтвердити, що всі включені дослідження відповідають меті огляду. Результати. У хворих після ортопедичних операцій на кульшових і колінних суглобах включення НМЕС до стандартної фізичної терапії дає змогу суттєво збільшити силу чотириголового м'яза стегна порівняно зі звичайною фізичною терапією. Рання активація може бути корисною для уникнення пригнічення функції й атрофії чотириголового м'яза, забезпечення пацієнта найефективнішим курсом реабілітації та повернення до активного способу життя після реконструкції передньої схрещеної зв'язки чи ендопротезування колінних суглобів. Також доцільно використовувати НМЕС як альтернативну механічну профілактику тромбозу глибоких вен і набряку в ранньому періоді після ендопротезування кульшового суглоба. У проаналізованих роботах відмічено, що пацієнти добре переносили призначення НМЕС на 1–2-й день після операції. Проте протоколи НМЕС дуже відрізняються, тому вибір параметрів стимуляції залишається на розсуд лікаря та, зазвичай, залежить від толерантності до стимуляції пацієнта.

Key words. Neuromuscular electrical stimulation, anterior cruciate ligament reconstruction, arthroplasty, hip joint, knee joint

Introduction

The incidence of anterior cruciate ligament (ACL) reconstruction operations [1] and total hip and knee arthroplasty [2] is increasing every year.

There is a need for continuous improvement of rehabilitation protocols for patients after surgery to provide them an opportunity to quickly restore normal range of motion and return to a higher life quality. The use of non-invasive neuromuscular electrical stimulation (NMES) as a supplement to standard rehabilitation programs has a wide range of applications.

In 2017, in response to inquiries from physiotherapists about recommendations for optimal muscle stimulation with NMES, six Canadian physical education teachers, clinicians, and electrophysical agent researchers reviewed and synthesized key data from the literature [3]. Clinical orthopedic practice shows that in the rehabilitation of patients after ACL reconstruction and total hip and knee arthroplasty it is advisable to start NMES on the 1–2nd postoperative day (POD). However, in the cited sources, the use of NMES was aimed only at strengthening and reinforcement of the quadriceps femoris. We conducted a more detailed analysis and considered the effectiveness of early appointment of NMES for the following conditions: prevention of thromboembolic complications after surgery on the lower extremities, reinforcing muscles and increasing their strength, reducing postoperative edema.

The aim of the study was to provide an evidence resource that can enable clinicians to effectively use electrical stimulation to improve muscle function in patients after orthopedic surgery and to increase awareness of the scope of neuromuscular electrical stimulation.

Material and methods

Three electronic databases (PMC, PUBMED and SCOPUS) were used to search for relevant literature published between the creation of the databases and December 2020. Additional articles were identified by analyzing bibliographies in systematic reviews. We have reviewed the full text of selected articles to confirm that all studies included meet the purpose of the review.

Results and discussion

Anterior cruciate ligament reconstruction

Muscle atrophy and weakness inevitably occur after an ACL injury, so physically active individuals often need ligament reconstruction to restore knee stability, improve lower limb function, and return to a normal lifestyle [4]. Due to limited movement and immobilization after surgery, the patient needs additional methods of early muscle activation. In the case of imperfect rehabilitation, complications caused by a decrease in muscle strength lead to dissatisfaction with the results of the operation and can accelerate the progression of arthrosis [5] or re-injury of the ligament [6], so improving muscle strength is the main goal to be achieved in the early stages of rehabilitation after ACL reconstruction.

The following stimulation parameters were used in the published studies: waveform mono- [7], two-phase pulse [7–10] or alternating current [11]; used frequencies involved 20–50 Hz of pulse current, 2,500 Hz of alternating current; pulse duration was 150–400 μs [7, 8, 10, 12], ON: OFF time (alternating current and pause links) 5–10: 2–110 s. The amplitude was set taking into account the patient's response.

I. Wigerstad-Lossing et al. [12] started NMES on the 2nd POD (session duration 40 min, 3 times a week, 6 weeks). They reported that among patients who received NMES during the period of immobilization after ACL reconstruction, the loss of isometric force (39 %) and the reduction of the cross-sectional area of the quadriceps femoris (23 %) were significantly smaller than in the control group (CG) (58 and 29 %, respectively). Moreover, an increase in the relative area of type 2 muscle fibers compared to type 1 indicates a more intense muscle contraction in patients receiving NMES. Summarizing the results of the study, the authors noted that NMES, combined with arbitrary muscle contraction during the therapy session, significantly protects against atrophy and prevents the development of secondary muscle weakness.

A. F. Anderson and A.B. Lipscomb [8] selected 100 patients who underwent ACL reconstruction using the same method and divided them into 5 groups to determine the effects of different treatments (some in combination): percutaneous electrical nerve stimulation (PENS), flexion immobilization or extensions, electrical myostimulation (EMS) and training with passive movements. Electrical stimulation was started on the 1st POD. Arbitrary muscle contraction was not performed concomitantly with EMS. The disadvantage was a very demanding protocol, namely 10 hours a day for 12 weeks, so 5 patients did not complete the study. The use of EMS did not reduce atrophy, but was effective in minimizing the decrease in force that occurs during immobilization. An unexpected advantage was a significantly greater amount of movement in patients after EMS compared with the groups of passive training and a significant re-

duction in the frequency of knee-femoral crepitation compared with all groups.

D. P. Currier et al. [9] combined the use of NMES and a pulsed electromagnetic field (PEMF). They divided 17 patients into three groups: I — NMES (n = 7), II — NMES/IEMP (n = 7), III — control (n = 3). NMES therapy was started on the 1st POD (session duration 30 min, 3 times a week, 6 weeks) in both groups. PEMF was added to the protocol on day 4. To determine the effectiveness, the hip circumference was evaluated before and 6 weeks after surgery. In groups I and II this indicator decreased equally well, but group II patients underwent a higher intensity of stimulation.

S. Hasegawa et al. [11] investigated the effect of electrical stimulation on the prevention of muscle atrophy in 20 patients in the early stages of rehabilitation after ACL reconstruction. Patients were randomly divided into two groups, particularly control (n = 10) and NMES (n = 10). Patients in the control group participated only in the usual rehabilitation program. In the second group, in addition to this protocol, NMES was used from the 2nd POD to 4 weeks after surgery (session duration 20 min, 5 times a week). The study involved stimulation of quadriceps and posterior thigh muscles, anterior tibia and triceps calves of the operated leg. As a result of the decrease in muscle strength of the quadriceps, the operated limb was significantly smaller in the group of NMES (1.2 %), compared with the control (39.2 %) 4 weeks after surgery. The recovery rate in the NMES group was higher than in the control after 3 months. The authors believe that the difference in muscle strength between the groups is due to the prevention of atrophy by using NMES for 4 weeks.

M. J. Toth et al. [7] published the results of a randomized, blinded, placebo-controlled study that comprehensively examined the effects of NMES on maintaining skeletal muscle size and function. The results of bilateral lateral broad thigh muscle biopsy were analyzed. Therapy with NMES was started as early as possible, but not later than the 3rd POD. The duration of the session was 60 minutes, 5 times a week for 3 weeks. Early use of NMES has been shown to reduce skeletal muscle fiber atrophy in myosin heavy chain (MHC) II and to maintain contractility in MHC I fibers. The results demonstrate the usefulness of early use of NMES to reduce atrophy and increase the force of contractions of the quadriceps femoris.

Hip replacement

Total hip arthroplasty is a well-known successful surgical procedure in the late stages of arthrosis. The development and improvement of surgical techniques, pain management strategies and enhanced postoperative rehabilitation help to improve the results of functional joint repair [10]. However, patients in the postoperative period may have complications, such as decreased muscle strength, edema of the operated limb, thrombosis of the veins of the lower extremities. The experience of modern physiotherapy shows that the inclusion of NMES in standard rehabilitation programs can effectively reduce the manifestations of complications.

Two small randomized clinical trials of the effects of NMES on the quadriceps femoris after hip arthroplasty have been reported in the literature. In one, the use of NMES was started 2 weeks after surgery [13], in the other [14] the effectiveness of standard rehabilitation, NMES and unilateral resistance training was compared. The use of NMES began on the 1st POD for 12 weeks. Stimulation parameters were as follows: waveform two-phase pulse current, frequency 40 Hz, pulse duration 250 μs, ON: OFF time 10:20 s, maximum amplitude that the patient can withstand, session duration 60 minutes. It was found that the functional activity of the muscles increased after NMES by 15 % more than in the group of standard rehabilitation [14].

In the first two weeks after total hip arthroplasty there is a high risk of deep vein thrombosis, and the peak of their occurrence is most often observed in 1–3 days. With this in mind, compression stockings and NMES are used effectively together with pharmacological measures to improve venous circulation of the lower extremities.

In two studies, NMES was used immediately after surgery to stimulate the calf muscles of both limbs (operated and non-operated) for 4 h [15, 16]. B. J. Broderick et al. [16] studied whether the use of NMES increases venous outflow from the lower extremity at rest in the early post-prosthetic period and to what extent patients can tolerate an extended session of NMES. Stimulation parameters: waveform two-phase pulse current, frequency 36 Hz, pulse duration 350 μs, a gradual increase of amplitude until a slight bending of the foot. The electrodes were placed under compression stockings. The authors found a favorable hemodynamic response to NMES in patients in the early postoperative period (increased peak and mean venous velocity, volumetric flow in the lower extremities compared with rest). All participants easily tolerated the four-hour NMES session.

In 2017, a clinical observation was conducted, which evaluated the effect of using a portable NMES device for the prevention of deep vein thrombosis [17].

After the operation, NMES was started for the first 24 hours, the course of treatment was 3 days. Usually, intensity at the level of 3–4 was used (according to the operating instructions of the device), depending on the patient's tolerance to stimulation, with a gradual increase in intensity. The use of NMES was found to increase blood flow in the deep veins of the lower extremity, dilate blood vessels and effectively reduce the incidence of deep vein thrombosis.

A randomized clinical trial was later completed comparing the effectiveness of a portable NMES device and compression stockings [18] for the prevention of deep vein thrombosis in patients after elective hip replacement. Hemodynamic reactions to the action of the device, edema of the lower extremities, the range of motion of the thigh were also evaluated, and Sit to Stand and Timed Up and Go tests were performed. Two cases of asymptomatic deep vein thrombosis were detected in a group of patients using compression stockings with vascular Doppler imaging 48 hours after surgery. In patients who used NMES, there was a general tendency to reduce swelling in the postoperative period, while the volume of the legs remained largely unchanged in the group using compression stockings. In addition, positive hemodynamic effects in the contralateral limb were found in the NMES group. Timed Up and Go test scores were better in the NMES group: (150 ± 152) % vs. (363 ± 257)% in the case of compression stockings ($p = 0.03$). No differences in Sit to Stand estimates in the thighs were found.

The use of NMES to reduce postoperative edema is also supported by the results of another clinical study [19], which analyzed the performance of 40 participants who started treatment with NMES ($n = 20$) or compression stockings ($n = 20$) on the 2nd POD. To evaluate the outcome, circumference of the ankle, knee, and thigh of both lower extremities was measured before, immediately after, and two days after surgery, then every day before discharge. NMES has shown a greater clinical effect in reducing edema compared with the use of compression stockings.

Knee arthroplasty

Total knee arthroplasty successfully relieves pain and improves function in patients with osteoarthritis, although the restoration of strength and function of the quadriceps muscle can occur over a long period of time [20]. NMES has been used for many years as an adjunct to traditional patient rehabilitation, as it can provide a more effective increase in strength and reduce the deficit of central activation of the quadriceps muscle than performing special exercises alone.

The following stimulation parameters were used in the above studies: waveform two-phase pulse current, frequency 35–100 Hz, pulse duration 250–600 μs, ON: OFF time 8–15: 8–45 s, individual, maximum allowable amplitude. In particular, R. S. Gotlin et al. [21] performed NMES from the 1st POD (2 times a day for 60 min) simultaneously with continuous passive movement on the simulator (main group) and compared the effectiveness of electrical stimulation with the performance of only conventional physiotherapy (control). In the subjects of the main group, the limitation of the extensor function decreased from 7.5° to 5.7°, and in the control group, on the contrary, the indicators increased from 5.3° to 8.3°. Also, the length of hospital stay after NMES was shorter compared to the control (6.7 days vs. 7.4).

It has been shown that administration of NMES from the 2nd POD (2 times a day, session duration 2 h) contributes to a significant increase in distance and walking speed in 6 (NMES — 176.1 m, control — 151.7 m), and 12 (NMES — 188.2 m, control — 155.9 m) weeks after surgery [22].

P. E. Mintken et al. [23] reported a clinical case where the appointment of NMES from the 2nd POD lasting 6 weeks resulted in improved quadriceps function and positive results on the Knee Injury and Osteoarthritis Outcome Score (KOOS), SF-36 Physical Component Score and Timed Up and Go tests, a 6-minute walk and stair climbing.

J. E. Stevens-Lapsley et al. [24] showed that early administration of NMES (from the 2nd POD for 6 weeks, 2 times a day, session duration 30 min) significantly reduced the loss of quadriceps muscle strength and improved functional performance after knee arthroplasty. The effects were most evident and clinically significant during the first month after surgery, and persisted throughout the year. During rehabilitation, patients should make every effort to maintain the maximum possible intensity of NMES to improve the strength of the quadriceps muscle. Usually, several sessions are performed so that the patient can get used to the intensity of stimulation [25].

The author's manuscript evaluated the effectiveness of prescribing NMES to reduce quadriceps activation deficit [26]. Treatment was started within 48 hours after surgery and continued for six weeks. Individuals receiving NMES were found to have greater quadriceps strength, a wider range of motion in the knee joints, and functional efficiency than the control group. Early recovery of quadriceps muscle by counteracting the development of activation deficiency contributed to long-term improvement in functional performance in patients receiving NMES.

Another randomized clinical trial shows that early appointment with NMES, along with a standard rehabilitation protocol, is more effective in reducing knee pain, increasing walking distance, and improving quality of life. In the NMES group, passive range of motion in the knee joints, Timed Up and Go test score, Western Ontario McMaster Osteoarthritis Index (WOMAC) and Short-Form 36 were better than in the control group [27].

Conclusions

In patients after orthopedic surgery on the hip and knee joints, the inclusion of NMES in standard physical therapy significantly increases the strength of the quadriceps muscle. Early activation can be helpful to avoid suppression of electrical excitability and atrophy of the quadriceps muscle, providing the patient with the most effective course of rehabilitation and return to active life after ACL reconstruction and knee arthroplasty. It is also advisable to use NMES as an alternative mechanical prevention of deep vein thrombosis and edema in the early postoperative period after hip arthroplasty. Patients, according to modern standards, after orthopedic surgery receive anticoagulation therapy. No adverse reactions in the form of bleeding have been reported in the literature, but NMES should be prescribed after hemodynamic stabilization of the patient. In the analyzed studies, patients tolerated the appointment of NMES well on the 1st–2nd POD. However, NMES protocols are very different, so the choice of stimulation parameters is left to the discretion of the physician and usually depends on the patient's tolerance to stimulation.

Conflict of interest. The authors declare no conflict of interest.

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EXPENDITURE OF EARLY INITIATION OF NEUROMUSCLE ELECTRICAL STIMULATION AFTER ORTHOPEDIC SURGERIES ON THE HIP AND KNEE JOINTS (LITERATURE REVIEW)

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