Original Article

Development and preliminary validation of a new protocol for postoperative rehabilitation of partial meniscectomy

ALHADI JAHAN[1] ✉, MARGARITA DMITRIEVNA[2], MIYA ISMAYILOVA[3]

[1]*School of Rehabilitation Sciences, University of Ottawa, Canada*
[2]*Department of Physical Rehabilitation, Belarusian State University, Belarus*
[3]*Interdisciplinary School of Health Sciences, University of Ottawa, Canada*

ABSTRACT

Background: Meniscal injuries are common among athletic populations and are one of the most common indications of knee joint surgeries. Meniscectomies are a common practice among orthopaedic surgeons in meniscal injury surgical treatment. Currently, no consensus exists for a standardized postoperative rehabilitation protocol after partial meniscectomy. Purpose: This article describes the development and validation of a new rehabilitation protocol for the management of meniscus injury after partial meniscectomy. Methods: A rehabilitation protocol for the postoperative meniscectomy was developed based on literature reviews. Evaluation from clinical experts were done by a 2-hour discussion with a group of seven clinicians to validate the protocol. Finally, an experimental design was used to test the effectiveness of the proposed protocol on a sample of 38 patients who had partial meniscectomies. Results**:** The final protocol included easy step-by-step directions for physiotherapists. The experts' validation process resulted in modifications related to clarity, feasibility, technical descriptions, and usability. Our experimental study showed significant improvement of knee joint functions compared to a conventional physiotherapy group. Conclusions: Our final protocol includes detailed instructions which a physiotherapist should be able to follow up rehabilitate patients who have undergone partial meniscectomy from the third day post-surgery until 8 weeks post-surgery. The

✉ **Corresponding author.** *School of Rehabilitation Sciences, University of Ottawa, Canada.*
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protocol is clear, easy to follow, and applicable in rehabilitation settings. **Key words:** MENISCECTOMY, REHABILITATION, KNEE JOINT, ATHLETES, MENISCUS INJURY, PROTOCOL.

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INTRODUCTION

Meniscal tears are among the most common knee injuries worldwide. In the USA, for instance, meniscal tears are the most common intra-articular lesions of the knee joint (Akatsu et al., 2015), and the most common indication for surgery in orthopaedic practice (Astur et al., 2016). Knee menisci are crescent-shaped structures of fibrocartilage located on the medial and lateral aspects of the knee joint. The word *meniscus* comes from the Greek word *mēniskos*, which means "crescent," diminutive of *mēnē*, meaning "moon"(Fox, Bedi, & Rodeo, 2012). The meniscus is an important weight-bearing structure that absorbs 50-70% of the load transmitted through the lateral and medial knee compartments (Bruns, Volkmer, & Luessenhop, 1993).

The meniscus plays other important functions in knee joint stability, lubrication, and congruity (Kurosawa, Fukubayashi, & Nakajima, 1980; I. M. Levy, Torzilli, & Warren, 1982; Wirth & Peters, 1997, pp. 123–144).

Meniscal injuries can cause considerable pain, disability, and resource utilization and may also accelerate the development of knee osteoarthritis (Englund, Guermazi, & Lohmander, 2009; Makris, Hadidi, & Athanasiou, 2011; Niu et al., 2011). Oftentimes, surgery is the best option in treatment of such injuries since the inner part of the menisci is avascular and injuries to it are incurable. In fact, about 1 million patients undergo meniscectomies annually in the US alone (Niu et al., 2011). Notably, the most common surgical procedure in orthopaedic clinics is the arthroscopic partial meniscectomy (Cullen, Hall, & Golosinskiy, 2009).

Rehabilitation treatments after partial meniscectomies vary; however, treatment usually lasts up to 8 weeks. Rehabilitation protocols for post-meniscectomy care may consist of cryotherapy, electrotherapy, ultrasound therapy, massage, joint mobilization, and exercise (P. C. Goodwin et al., 2003). The rehabilitation treatment aims to control pain, decrease swelling, maximize knee joint range of motion (ROM), and help patients regain a normal walking pattern with full weightbearing (Brindle, Nyland, & Johnson, 2001). On the one hand, supervised rehabilitation showed superiority over home-based programmes in some studies (Moffet, Richards, Malouin, & Bravo, 1993; Vervest, Maurer, Schambergen, Bie, & Bulstra, 1999). However, other studies suggest that there is no significant difference between supervised rehabilitation and home-based rehabilitation programmes (P. C. Goodwin et al., 2003; Rockborn, Hamberg, & Gillquist, 2000). A recent systematic review by Papalia and colleagues (2013) on the rehabilitation programs following knee surgery concluded that the heterogeneity of the rehabilitation protocols used along with other variables such as comorbidities and motivation, could influence patient outcomes and deserve to be accounted for in future research (Papalia et al., 2013). Thus, all potential sources of heterogeneity were accounted for in the development of the current protocol.

At present, there is no consensus among scholars and clinicians as to what rehabilitation protocol is best for the postoperative rehabilitation regimen for patients who have undergone partial meniscectomies. Our research goal was to develop and validate a rehabilitation protocol for the postoperative phase of meniscectomies that can be applied in rehabilitation settings as well as in community-based programmes. The protocol will give clear step-by-step instructions to a physiotherapist on how to move from one regimen phase to the next based on measurable criteria. Also, it will help therapists set up specific goals and objectives in each phase of the postoperative rehabilitation process.

Since the protocol was developed and validated in two phases, we describe methods and results for phase I, then methods and results for phase II, followed by an overall discussion and conclusion. The goal for phase I was to use the available literature to develop a draft protocol that contained all the necessary elements and evidence-based practices for the rehabilitation of knee joint functions after meniscectomies. Phase II involves the gathering of expert opinions in order to identify the limitations and strengths of the draft protocol, as well as to validate the developed protocol. The main research question that was addressed with experts was: can a therapist apply and follow our developed rehabilitation protocol through the rehabilitation course? Finally, in phase II, the protocol was tested on a sample of patients after undergoing partial meniscectomy. The research question for phase II was: do patients with partial meniscectomy who complete the proposed protocol report improved knee functions compared with those who are managed by conventional physiotherapy modalities?

PHASE I: PROTOCOL DEVELOPMENT

Methods

In phase 1, a comprehensive literature search was performed in both English and Russian databases, which included articles published from January 1960 to May 2016. English databases included: Medline, PubMed, Pedro and CINAHL. Russian databases included: The National Library of Belarus (Minsk), the Russian State Library (Moscow), and the Russian National Library (St. Petersburg). The purpose of this literature review was: (1) to identify rehabilitation protocols for postoperative meniscal damage that could be used to inform the development of our protocol, and (2) to explore the content and design of existing protocols which could be incorporated into our protocol.

The primary search was conducted using terms such as: “rehabilitation” AND “program” OR “protocol” OR “guidelines” AND “Knee injury” OR “meniscus injury” OR “meniscectomy” in titles, abstracts, and key words. A total of 86 citations were identified and reviewed. Two researchers evaluated the identified articles according to pre-defined inclusion/exclusion criteria by using an analysis grid adapted from the instrument evaluation framework proposed by Rudman and Hannah (Rudman & Hannah, 1998). This framework suggests using five evaluation categories: (1) clinical utility, (2) standardization, (3) purpose, (4) psychometric properties, and (5) client’s perspective. Additionally, our evaluation grid also covered: 1) the protocol's content; 2) the protocol’s relevance to post-operative rehabilitation of partial meniscectomy; 3) the availability of at least one published article outlining a protocol’s development and/or validation. Out of the 86 studies retrieved, 27 were excluded on the first round (title and abstract screening), 45 were excluded on the second round (full text screening). Citations were excluded if they met at least one of the exclusion criteria. The methodological quality of the retrieved studies was assessed and classified based on the Oxford Centre for Evidence-Based Medicine (OCEBM) (Howick et al., 2011). In this classification, five levels of evidence were recognized:

- Level 1: includes only systematic reviews of randomized trials
- Level 2: entitles randomized clinical trial
- Level 3: includes non-randomized cohorts and follow up studies
- Level 4: includes case-series or case-control studies
- Level 5: includes expert opinions

To broaden our search results/scope, we included non-academic sources (i.e. grey literature) in Level 5 such as clinics’ websites, organizations’ websites, and unpublished protocols.

A total of 13 full-text articles were further analysed. Our literature review revealed 9 postoperative rehabilitation protocols that had some research support. Research support entails the availability of at least one published research paper describing usage of the protocol or reporting on its development and/or its validation. Figure 1 illustrates the review process and the reasons why we excluded 77 citations.

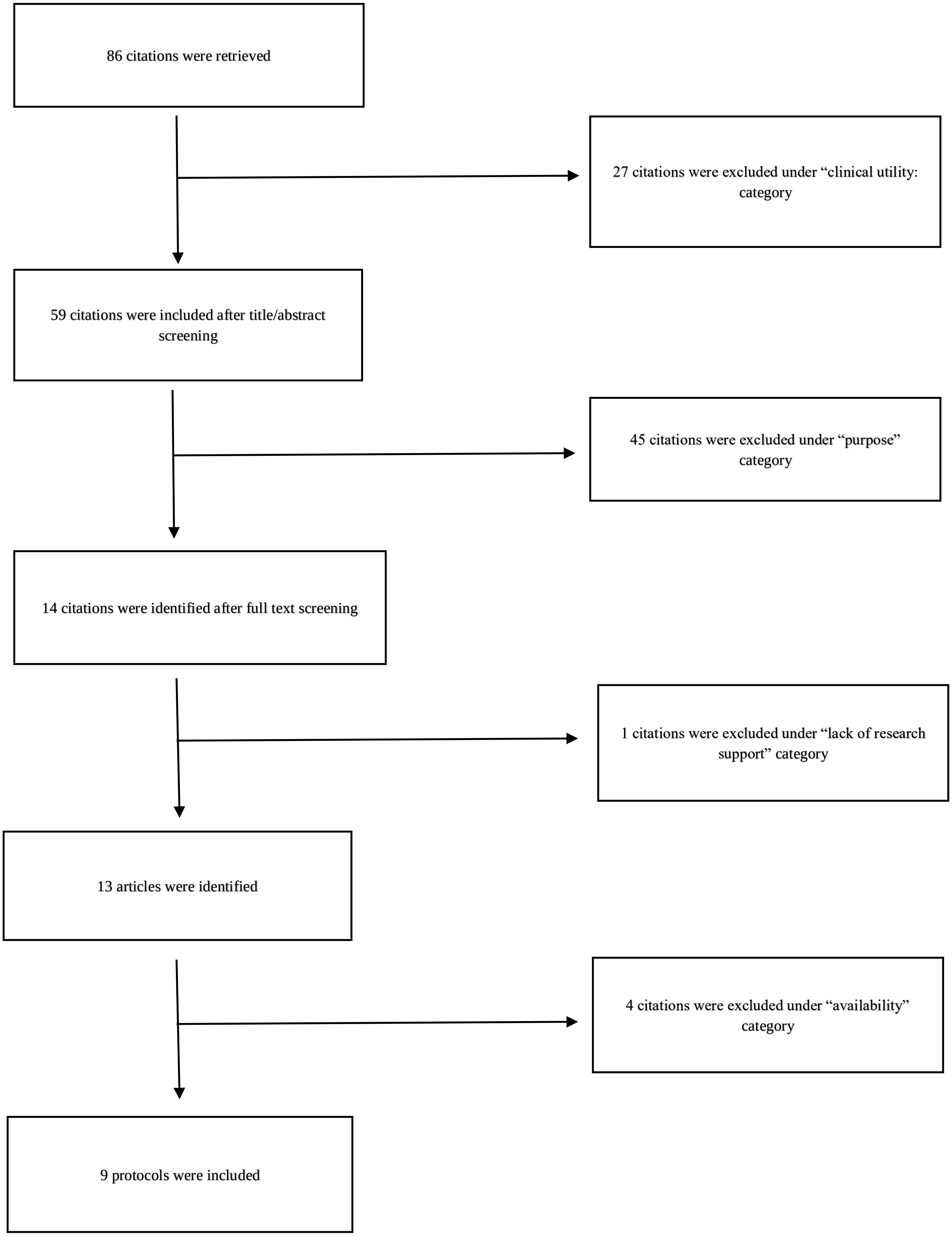

Figure 1. Literature review flow chart.

Protocols were included for review based on discussions with experienced clinicians. The nomination of experts was made based on 2 main criteria: 1) research interest in knee joint injuries and rehabilitation, and 2) clinical experience. After a series of meetings with experienced clinicians, the following interventions were included: massage, hydrotherapy (e.g., underwater massage or pool exercise), therapeutic exercise (e.g., gymnastics, yoga, resistance training), electrotherapy (e.g., TENS, Interferential current, dynamic current), ultrasound therapy, and thermotherapy (e.g., hot packs, paraffin wax, infrared). We excluded interventions that have poor support in literature on the management of knee joint injuries, such as: acupuncture, manual therapy, magneto therapy, short wave diathermy, manual therapy, traditional treatment strategies (e.g., Chinese traditional medicine, herbal treatments), behavioural, and educational interventions. Phonophoresis (medication and ultrasound), and iontophoresis (medication and electrical current) were excluded because they mix medications and physiotherapy modalities. Alternative medicine and traditional medicine were also excluded because they are not considered physiotherapy interventions (Albright et al., 2001; Kearney, Cioppa-Mosca, Peterson, & MacKenzie, 2007).

A draft protocol was developed by combining elements of the identified protocols as well as incorporating a hydrotherapy program. The reasons for focusing on hydrotherapy are discussed in discussion section. The initial draft of the protocol was developed using expert opinions, team discussions, and a checklist. Then, the draft protocol was sent to experts in the fields of medical rehabilitation, physiotherapy, sports medicine, and orthopaedics for review. The draft protocol is an 8-week course which consists of cryotherapy, neuromuscular electrostimulation, mobilization exercise, stretching and strengthening exercise, massage, proprioceptive training, functional training, gait re-education, and hydrotherapy sessions.

Draft review

Seven clinicians with extensive experience in musculoskeletal physiotherapy were contacted to evaluate the draft of the protocol (3 physiotherapists, 2 sports medicine practitioners, and 2 orthopaedic physicians). The nomination of experts was made based on 2 main criteria: 1) research interest in knee joint injuries and rehabilitation, and 2) clinical experience. In general, they commented that the draft protocol was clear and useful. However, they emphasized the importance of the language being used, the clarity of the instructions, and patient preferences on program content, as these factors are important in patient adherence to the treatment sessions (Martin, Williams, Haskard, & DiMatteo, 2005). One physiotherapist highlighted the importance of setting specific goals for each phase of the rehabilitation course. For the hydrotherapy portion of the regimen, most of the experts emphasized that safety and privacy issues that must be considered for the successful implementation of such protocols.

Draft modifications

Based on clinicians' feedback, many changes have been applied to the protocol. For instance, patient preference on the chronological order of exercises and modalities has been considered (if the order is not clinically important). Also, a comprehensive revision to the language, the questions, and the literacy level has been conducted to ensure that the protocol is easy to understand. For example, using adjectives when giving instructions may be confusing, therefore, only simple, direct instructions were used. Furthermore, the amount of text was reduced as much as possible and visual formats, such as charts, pictures, and diagrams were used whenever necessary. For the hydrotherapy portion of the regimen, private and supervised pools were recommended to patients in order to meet safety and privacy requirements of each individual.

PHASE 2: PROTOCOL VALIDATION

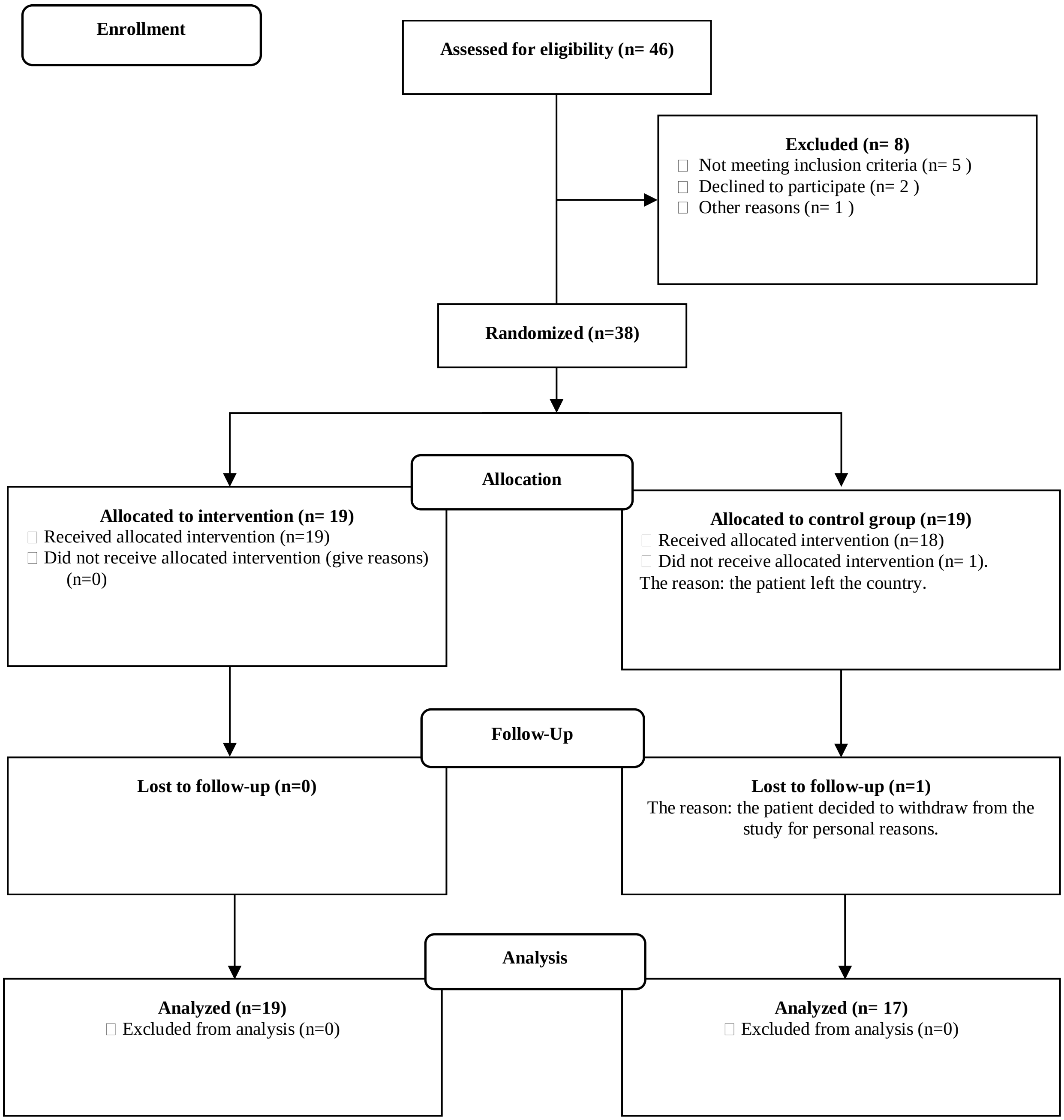

Figure 2. The progress through the study phases.

Methods

In phase 2, the final version of the protocol was tested on a sample of athletes who had meniscus injuries and had undergone a partial meniscectomy. In this study, a two-group, single-blinded, randomized (1:1 ratio), controlled, and repeated-measures was performed to examine the differences between the two groups over time. Thirty-eight patients (7 females and 31 males, mean age = 28.3 ± 6.7) with uncomplicated partial meniscectomies were included. Participants were identified from patients recovering from partial meniscectomy at two hospitals in Minsk (Belarus) over an 8-week period. Patients who elected to participate and provided written consent were randomized and allocated to an experimental group (following the developed protocol) or to a control group (conventional physiotherapy). The selection procedure is based on the inclusion and exclusion criteria. A simple randomization technique was applied by using "flipping a coin method". The physiotherapists use an assessment protocol to evaluate eligibility. The protocol is based on The Orthopaedic Section of the American Physical Therapy Association (APTA) (Logerstedt, Snyder-Mackler, Ritter, & Axe, 2010). Subjects were eligible to participate in the study if they were athletes or actively engaged in any sport, were between 18 and 35 years of age, and recently had underwent a partial meniscectomy. Eligible patients were required to speak and understand the language of instruction, be residents of the Minsk region, and be able to meet program requirements to be included. Participants were excluded if they had any complications after surgery or had any other related injuries in the same or the contralateral lower extremity that needed close medical attention. Also, patients were excluded if they could not meet the program timeline. Before or within 48 hours after the surgery, eligible participants were given written and verbal information about the study and were invited for participation. A total of 38 participants (7 females and 31 males) signed an informed consent form and agreed to participate and attended the pre- and post-test sessions. The flow CONSORT diagram (Figure 2) shows the progress through the study.

Rehabilitation Program (intervention)

The rehabilitation protocol is an 8-week course which consists of three phases (See Table 1). Patients in both groups were treated by registered physiotherapists. The sessions took place 3 times per week and every session lasted approximately 2 hours. Massage therapy and hydrotherapy sessions took place on separate days rather than the three days scheduled for physiotherapy.

Table 1. The proposed rehabilitation protocol.

Phase I (week 1)	
Goals	1. To control inflammation, pain, and effusion. 2. To allow early healing. 3. To gain full passive knee extension. 4. To gradually increase knee flexion 5. To educate the patient self-exercises and the progress of his/her rehabilitation course. 6. To restore functional independence.
Immobilization	Hinged Knee Brace: 1. Locked in full extension for mobility and sleeping. 2. Should be removed for hygiene and physiotherapy sessions.
Massage	1. Subject in prone position: Swedish techniques, including effleurage and petrissage (15-20 mins). 2. Subject in supine position: Swedish techniques, including effleurage and petrissage (15-20 mins).

	3. Subject side-lying: Myofascial release for tensor fasciae latae, iliotibial tract and vastus lateralis muscle (15-20 mins). 4. Session closure: Effleurage, passive range of motion and passive gentle stretching (5-10 mins).
Modalities	1. Ice, compression, and elevation before and after exercise for 15-20 minutes. 2. Muscle Stimulation: Electrical muscle stimulation to quadriceps during voluntary quadriceps exercises. 3. TENS to relief pain, if necessary.
Exercise	1. Deep breathing exercises (every hour) 2. Coughing exercises (every 2 hours). 3. Foot and leg exercises (4-6 times): - Ankle pump. - Ankle circles. - Heel slides up to 90° flexion. - Straight-leg-raise for operated leg. 4. Stretching exercises: - Hamstrings muscles. - Gastrocnemius and soleus muscles. 5. Changing position (every hour). 6. Walking (several times a day).
Weightbearing	As tolerated by 2 crutches.
Red flags	1. No weightbearing at flexion angles greater than 90°. 2. Pain and discomfort should be closely monitored. 3. Dizziness during walking.
Phase II (weeks 2 to 4)	
Criteria to Progress to Phase II: 1. Quadriceps Control (the patient is able to perform good quadriceps set). 2. Full passive knee extension 3. Passive ROM is (0-90°).	

	4. Good patellar mobility. 5. Minimal joint effusion. 6. Independent mobility.
Goals	1. To maintain full passive knee extension (at least 0 to 5° hyperextension) 2. To gradually increase passive knee flexion. 3. To gradually increase weightbearing. 4. To minimize joint effusion and pain. 5. To improve muscle control. 6. To normalize patellar mobility.
Immobilization	1. Brace kept locked for mobility and sleeping 2. ROM brace can be used for mobility from week 3 on.
Massage	1. Subject in prone position: Swedish techniques, including effleurage and petrissage (15-20 mins). 2. Subject in supine position: Swedish techniques, including effleurage and petrissage (15-20 mins). 3. Subject side-lying: Myofascial release for tensor fasciae latae, iliotibial tract and vastus lateralis muscle (15-20 mins). 4. Session closure: Effleurage, passive range of motion and passive gentle stretching (5-10 mins).
Modalities	1. Continue use of ice, compression, and elevation. 2. TENS to relief pain, if necessary.
Exercise	1. ROM Guidelines: gradually increase passive ROM as follows: - Week 2: from 0 to 100°. - Week 3: from 0 to 110°. - Week 4: from 0 to 120°. 2. Passive ROM exercises and stretching are continued. 3. Strengthening exercises - Multi-angle quadriceps isometrics. - Straight leg raise (in 4 planes). - Knee extension 90-0°. 4. Proprioception/Neuromuscular Training

	- Open Kinetic Chain passive/active joint repositioning 90°, 60°, 30°. - Closed Kinetic Chain joint repositioning during squats/lunges. 5. Balance training. 6. Bicycle (if ROM is appropriate).
Weightbearing	1. 50% or as tolerated. 2. Crutches can be discontinued when safe and proper gait is reached (usually in 3 to 4 weeks, unless otherwise suggested by the physician).
Hydrotherapy	1. Starts in week 3 (2-3 sessions per week) 2. Lasts from 30 to 50 minutes. 3. Water temperature ranges from 37.5-38°. 4. All safety and privacy issues should be considered. 5. Exercises: - Shallow Water Exercises: (Warm-up, Walking forward, backward, sideways with emphasis on quadriceps control and symmetry, and Balance/Proprioception training). - Open Chain Deep Water Exercise: (deep water walking, hip flexors/hamstrings' stretching, and strengthening exercise as tolerated). - Closed Chain Deep Water Exercises: (Standing on barbell/kickboard with or without assistance).
Red flags	1. Avoid twisting, deep squatting and stooping. 2. Avoid hamstring curls.
Phase III (weeks 5 to 8)	
Criteria to Progress to Phase III: 1. Active Range of Motion (0-120°). 2. No or minimal pain during full weightbearing. 3. No or minimal pain during exercise. 4. Minimal to no joint effusion. 5. Normal gait mechanics.	

6. Hamstrings' and quadriceps' strength in Closed Kinetic Chain are good.	
Goals	1. To restore full knee ROM (from 0° to 125°) 2. To obtain normal gait pattern in any surface. 3. To improve lower limbs' strength. 4. To enhance proprioception, balance, and neuromuscular control. 5. To improve muscular endurance. 6. To prepare the patient for a community-based program (advanced activity phase).
Immobilization	1. Discontinue brace, unless otherwise suggested by the physician. 2. Knee sleeves may be used to control swelling, and support.
Massage	1. Subject in prone position: Swedish techniques, including effleurage and petrissage (15-20 mins). 2. Subject in supine position: Swedish techniques, including effleurage and petrissage (15-20 mins). 3. Subject side-lying: Myofascial release for tensor fasciae latae, iliotibial tract and vastus lateralis muscle (15-20 mins). 4. Session closure: Effleurage, passive range of motion and passive gentle stretching (5-10 mins).
Modalities	Continue use of ice, compression, and elevation.
Exercise	**Week 5:** 1. Continue isometric strengthening program. 2. Closed Kinetic Chain quadriceps strengthening exercises. 3. Open Kinetic Chain for hamstrings. 4. Single leg raise with resistance. 5. Core stability exercises. 6. Stretching exercises. 7. Patellar mobilization. 8. Gait training 9. Stationary Bicycle (mild to moderate resistance). 10. Unloading treadmill walking

	Week 6-7: 1. Continue all exercises. 2. Balance training on tilt boards. 3. Wall slides/squats. **Week 8:** 1. Continue all exercises. 2. Leg Press (0°-100°). 3. Perturbation Training. 4. Isokinetic exercises. 5. Bicycle for endurance. 6. Stair Stepper Machine for endurance.
Weightbearing	Full weightbearing (100%).
Hydrotherapy	1. Shallow Water Exercises: - Continue with previously outlined shallow water exercises. - Add plyometrics on/off step. - Sports specific/functional exercises if indicated. 2. Open Chain Deep Water Exercises: - Continue with stretches if indicated. - Continue with strengthening, cardiovascular. 3. Closed Chain Deep Water Exercises: - Continue with exercises still difficult on land.
Red flags	1. Avoid twisting, pivoting, running and deep squatting.

Outcome measures

To evaluate rehabilitation progress, all participants were assessed two times: 48 hours after surgery, and at the end of week 8 (immediately after the end of the proposed protocol). A 48-hour period after surgery was practical and realistic, since contacting participants and making all necessary arrangements usually takes 1-2 days. Also, a 48-hour waiting time was practical because orthopaedic surgeons apply a compression bandage which remains on the knee for about 2 days. Main outcome measurement was achieved by measuring active and passive knee range of motion (ROM), measuring quadriceps and hamstring muscles' strength, and thigh muscle circumference. The active and passive range of motion (ROM) of knee joints was measured by using a manual goniometer. Goniometers have been used in physiotherapy practice and research for decades, and their validity and reliability has been confirmed by many authors (Brosseau et al., 1997; Farooq, Bandpei, Ali, & Khan, 2016; Gajdosik & Bohannon, 1987; Gogia, Braatz, Rose, & Norton, 1987; Nussbaumer et al., 2010). Quadricep and hamstring muscle strength was measured by the manual muscle test (MMT). There is a strong recommendation in literature to use MMT as it is easy to administer and reliable muscle test (Ageberg, Thomeé, Neeter, Silbernagel, & Roos, 2008; Cuthbert & Goodheart, 2007; Mendell & Florence, 1990; Rider et al., 2010; Sapega, 1990). Thigh circumference was measured using a centimetric tape. Measurements were performed to determine the degree of atrophy or hypertrophy of the muscles and to detect possible edema of the joints. The measurements were carried out by the same examiner three times, and the mean value of the three measurements was recorded. The feasibility, validity, and reliability of the circumference measurement is well established in literature(Doerti, 1993, pp. 107–123; Labs, Tschoepl, Gamba, Aschwanden, & Jaeger, 2000). These measures are considered by the team to be comprehensive and to most likely reflect clinical outcomes.

Statistical Analysis

Data was analysed using SPSS software (version 19, SPSS Inc., Chicago, IL). Data was expressed as means and standard deviation (SD) for descriptive data. Student's t-test was used to determine any differences in knee joint ROM and quadriceps and hamstring muscles strength between the groups in both operated and healthy limbs over time. This test was chosen because it is relevant to our study sample size and variables of interest. Due to the descriptive nature of this investigation, the level of significance was maintained at P-value < 0.05. The significant differences between the two groups longitudinally during the evaluation of treatment effectiveness are presented in the following section.

RESULTS

Among 46 patients screened, 38 were eligible to participate in the study. The mean age was 28.3 ± 6.7, ranging from 18 to 34 years old. A total of 31 individuals were male and 7 were female. Mean weight of patients was 69.6±6.3 kilograms, ranging from 54 to 79 kilograms, and mean height was 1.6±0.06 m, ranging from 1.61 to 1.94 meters. Out of 38 participants, 23 patients underwent partial meniscectomy of the right knee and 15 of them had the surgery on the left knee. There were no any underlying diseases in all the participants. There was a history of anterior cruciate ligament (ACL) reconstruction in 1 patient, lateral collateral ligament's (LCL) tear in 2 individuals.

The results of our study characterizing the strength of the thigh muscles before and after the intervention are presented in Table 2. The use of therapeutic exercise in the period of immobilization, followed by the long-term use of exercise and hydrotherapy has significantly improved functional capacity of the operated knee.

Table 2. Thigh muscle strength of the operated limb before and after rehabilitation sessions.

Indicator	Before	After
Anterior thigh muscles' strength, H	134.00 ± 7.38	172.00 ± 10.33* t = 9.28
Posterior thigh muscles' strength, H	81.50 ± 6.26	129.50 ± 7.24* t = 13.98

*(Note: * p-value < 0.05)*

In addition to increasing the strength of the operated limb's muscles, the proposed protocol has significantly improved the strength of the muscles of the healthy limb (Table 3).

Table 3. Thigh muscles' strength of the healthy limb before and after rehabilitation sessions.

Indicator	Before	After
Anterior thigh muscles' strength (quadriceps), H	180.50 ± 7.24	190.50 ± 5.99* t = 4.24
Posterior thigh muscles' strength (hamstrings), H	123.00 ± 4.22	131.50 ± 6.26* t = 3.13

*(Note: * p-value < 0.05)*

By comparing the muscle strength of the operated limb and healthy limb, we did not find significant differences in the strength of the hamstrings. However, the difference was significant in the Quadriceps (Table 4).

Table 4. Comparison between characteristics of thigh muscles' strength between operated limb and healthy limb after rehabilitation.

Indicator	Operated leg	Health leg
Anterior thigh muscles' strength, H	172.00 ± 10.33	190.50 ± 5.99* t = 4.65
Posterior thigh muscles' strength, H	129.50 ± 7.24	131.50 ± 6.26* t = 0.63

*(Note: * p-value < 0,05)*

The main function of the knee joint is flexion/extension which provide a person with the ability to walk, run, jump, lift objects, climb stairs, and squat. Loss of range of motion in the knee can affect the entire lower limb (DeHaven, Cosgarea, & Sebastianelli, 2003; Mohtadi, Webster-Bogaert, & Fowler, 1991; Parvizi et al., 2006). The aim of the rehabilitation program was to restore patients' range of motion in their knees after undergoing partial meniscectomies. Limitation in range of motion in the joints consists of the following main factors:

1. Lack of elasticity of connective tissues or joints.
2. Muscular tension (Shoji, Solomonow, Yoshino, D'Ambrosia, & Dabezies, 1990).
3. Lack of coordination and strength in case of active movement.
4. Restriction of bone and joint structures (Holla et al., 2011).
5. Pain.

Our results indicate that the developed protocol improved range of motion in the knee joints by overcoming existing factors that limit range of motion in the knee joint. Additionally, our protocol has significantly increased both active and passive range of motion (Table 5).

Table 5. Range of motion in the operated leg before and after rehabilitation.

Indicator	**Before**	**After**	**Percentage, %**
Active flexion, degrees	65.70 ± 2.31	104.60 ± 0.08* t = 5,30	59.20 ± 1.21
Passive flexion, degrees	94.00 ± 2.75	115.23 ± 0.09* t = 24.34	22.58 ± 1.37

*(Note: * p-value < 0.05)*

Interestingly, the proposed rehabilitation program not only improved range of motion of the operated knee, but also increased range of motion in the healthy knee (Table 6).

Table 6. Range of motion in the healthy leg before and after rehabilitation.

Indicator	**Before**	**After**	**Percentage**, %
Active flexion, degrees	111.31 ± 1.08	118.71 ± 0.07* t = 4.54	6.65 ± 0.13
Passive flexion, degrees	120.43 ± 1.10	136.31 ± 0.08* t = 6.32	13.18 ± 1.21

*(Note: * p-value < 0,05)*

The effectiveness of the proposed rehabilitation program was evaluated by comparing the results before and after the intervention. The initial measurements of the ROM of the operated joint were carried out after removal of immobilization, both in the experimental group and control group. As shown in Table 6, the mean degree of flexion (ROM) among patients in the experimental group and the control group before the intervention were similar: (73.30 ± 12.31) and (75.20 ± 13.21) degrees, respectively. However, after the intervention (by the end of week 8), the mean degree of flexion (ROM) among patients in the experimental group comprised of (123.30 ± 11.59) degrees, whereas, the mean degree of flexion (ROM) in the control group was (108.30 ± 17.15) degrees. There were significant differences between all the average measures for the range of motion before and after the intervention (p-value < 0.05).

Table 7. Comparison between knee flexion of experimental group and control group before and after the intervention.

Indicator	**Experimental group**		**Control group**	
	Before	**After**	**Before**	**After**
Flexion, degrees	73.30 ± 12.31	123.30 ± 11.59* t = 20.682	75.20 ± 13.21	108.30 ± 17.15* t = 0.333

*(Note: flexion ROM in both groups before the intervention are similar, * p-value < 0.05)*

DISCUSSION

The goal of this study was to develop and test a protocol for the rehabilitation of knee joint functions after partial meniscectomy. Generally, patients with meniscus injuries can be classified into 2 categories: 1) those with acute injuries (mainly athletes between the ages of 18 to 40 years), and 2) those with degenerative injuries (mainly middle-aged or elderly individuals). Postoperatively, patients report symptoms such as pain, joint effusion, limited ROM, functional changes, neuromuscular and biomechanical changes, loss of quadriceps muscle strength, and a reduced quality of life (Durand, Richards, Malouin, & Bravo, 1993; Glatthorn, Berendts, Bizzini, Munzinger, & Maffiuletti, 2010; Peter C. Goodwin & Morrissey, 2003; Magyar, Illyés, Knoll, & Kiss, 2008).

Rehabilitation of patients following partial meniscectomy requires a deep understanding of the anatomy and biomechanics of the lower limb. The protocol presented here is geared towards patients undergoing arthroscopic partial meniscectomy and should be modified to consider any other injuries or surgeries. The goal of this rehabilitation protocol is to optimize knee joint function for successful outcomes in patients. Early objectives after surgery are: control of pain and swelling, increases in knee range of motion (ROM), and restoration of walking with full weightbearing.

Protocol development consisted of two phases: 1) reviewing and analysing existing literature on rehabilitation protocols for postoperative partial meniscectomy, and 2) to test the proposed new protocol. The literature review was important to guide and inform the development of the draft protocol. The opinions and feedback of clinicians involved in treatment programs of the target population were also equally important in the content validation and evaluation of the proposed protocol.

Our literature review showed significant inconsistency in the postoperative protocols in many issues, such as type and duration of immobilization, weightbearing status, modalities being used, and the progression of the protocol. Currently, there is no consensus among orthopaedic surgeons on optimal weightbearing loads. In-depth analysis of our dataset revealed disagreements between scholars over restricted weightbearing. The use of different rehabilitation protocols showed insignificant differences among restricted and non-restricted weightbearing (O'donnell, Freedman, & Tjoumakaris, 2017). Thus, for our protocol, we started with 50% weight bearing or as tolerated by the patients in week 1 and gradually increased weight bearing until 100% by the end of week 8.

Surprisingly, hydrotherapy was rarely mentioned in literature as part of rehabilitation protocols in postoperative rehabilitation of partial meniscectomy, although it showed superiority over land-based programs (McClintock, Kirkley, & Fowler, 1995; Tovin, Wolf, Greenfield, Crouse, & Woodfin, 1994). However, when hydrotherapy had started in our protocol, participants showed significant improvements in ROM, muscle strength and other unreported variables in our study, such as pain. Most importantly, hydrotherapy provided psychological encouragement and motivation to the; participants to attend and complete the rehabilitation program, since adherence to rehabilitation sessions has been widely reported as a challenge for such populations (Fisher, 1990; A. R. Levy, Polman, Clough, & McNaughton, 2006; Taylor & May, 1996). Hydrotherapy cannot be started until wounds have properly closed to avoid any infections. Research suggest that wound closure can happen in 2 – 2.5 weeks (Kelln, Ingersoll, Saliba, Miller, & Hertel, 2009). To account for that limitation, we started hydrotherapy sessions in week 3 to give the wounds time to completely heal.

Intra-articular joint effusion in the knees is common in injuries and after surgeries (Zalta, 2008). Joint effusion usually occurs due to an inhibitory reflex in the quadriceps muscle, with the most significant inhibitory response taking place in the vastus medialis oblique muscle (Torry, Decker, Viola, O'Connor, & Steadman, 2000). The vastus medialis oblique muscle plays a significant role in the stabilization of the patella and any interruption of the contractibility capacity of this muscle can negatively influence the alignment of the patella (Grelsamer, 2000). Therefore, intra-articular joint effusion and diminished muscular activity of the quadriceps muscle can cause major changes in normal gait patterns (Torry et al., 2000). Thus, it is very important to focus on this muscle group as early as possible. In our protocol, massage therapy was introduced early to avoid all the aforementioned complications as well as to reduce postoperative inflammation by lymphatic drainage massage (Ludwig, 2000).

Massage therapy sessions started as early as the third day after surgery. Eight therapeutic massage sessions were given to all participants in the intervention group over an 8-week period (one session per week). Sessions averaged from 45 to 60 minutes. Massages were administered to both the operated and healthy limbs. The primary goal of the massage therapy sessions post- surgery was to control inflammation. Afterwards, the focus was to decrease muscles' hypertonicity and to increase the length and elasticity of the tensor fasciae latae, iliotibial tract, and hamstrings (Hendrickson, 2002, 2009).

To assess whether the new protocol is helpful in obtaining meaningful outcomes, an experimental design was used to test its effectiveness longitudinally on thirty-eight participants compared to a conventional physiotherapy program. The initial outcomes of the postoperative rehabilitation program, as compared to the results of the control group, included improvements in the range of motion (ROM) of the operated knee, improvements in quadriceps and hamstrings strength, and decreases in joint effusion as measured by thigh circumference. The findings from this study demonstrated that 8 weeks of structured rehabilitation with a hydrotherapy component, significantly improved muscle strength and range of motion (ROM) of the operated knee joints to almost the same level as the healthy limb. However, thigh circumference measurements were not statistically significant (5% at week 2 and 1% at week 8). Our findings are in line with previous research by Kelln et al (2009) and others (Czamara, Tomaszewski, Bober, & Lubarski, 2011; Kelln et al., 2009).

In our study, we instructed patients to train both the operated and the healthy limb at the same level of resistance. The results were promising (see Table 3) since the proposed protocol not only improved the muscular strength of the operated limb but also significantly improved muscle strength in the healthy limb. These results are in agreement with previous research (American College of Sports Medicine, 2009; Rohman & Tompkins, 2015). Our participants' characteristics were relatively homogenous because they were active athletes between the ages of 18 and 35 years. However, when thinking about the general public, patients with the same diagnosis are never identical and do not have identical treatment/rehabilitation needs (John T. Cavanaugh & Killian, 2012). Therefore, individualization of treatment regimens is the most important consideration that should guide the rehabilitation process (J.T. Cavanaugh, 1991, pp. 59–69).

Furthermore, another important consideration to account for is the pre-injury condition of patients. A patient may be a professional athlete, a recreational athlete, or not an athlete at all - thus, the pre-injury physical condition is a very important factor to consider in rehabilitation regimens for the general populations. Injury type, injury complexity, surgery type, surgery timing, and the healing process determine the type of rehabilitation protocol appropriate for a patient (Frizziero et al., 2013). Regarding the duration of our proposed protocol (8 weeks), we found in the literature that muscle strength and knee ROM generally return to preoperative status in 6 weeks (Matthews & St-Pierre, 1996; Wheatley, Krome, & Martin, 1996). After discussions with experts in the field, we extended the protocol until 8 weeks to make sure that gait pattern, weightbearing, balance, and muscle control reached optimum levels by the end of week 8. After week 8, an advanced exercise program in the community was recommended to all participants.

At the end of the process the protocol was validated, demonstrating that our designed protocol was appropriate for our aim to restore knee joint functions in patients after partial meniscectomies. The literature review revealed poor scientific support for rehabilitation protocols for postoperative partial meniscectomies. High variation exists between postoperative rehabilitation protocols. Currently, no consensus among clinicians and scholars is present on many issues regarding postoperative rehabilitation of partial meniscectomies. The ideal parameters for range of motion (ROM) and weightbearing after surgery are two examples of variation and uncertainty among scholars (O'donnell et al., 2017). Most reviewed protocols had no published information pertaining to the development or validation of their rehabilitation program. With a few exceptions, most of the identified protocols are institution-based programs with little or no published literature related to them. Furthermore, there is no any framework or tool, to our knowledge, that can be used to evaluate rehabilitation protocols for the postoperative phase of meniscectomy. Thus, the framework proposed by Rudman and Hannah (Rudman & Hannah, 1998) was adapted and modified in cooperation with a panel of experts to meet the purpose and nature of the proposed protocol. The obvious limitation of our study is the sample size. Due to the time limit for this study, we could only recruit 38 participants. However, we expect more refinement and updates to our protocol by other researchers using rigorous designs.

CONCLUSION

Meniscal injury is among the most common knee injuries, especially in athletic populations. Partial meniscectomy is a surgical approach to remove the damaged part of the meniscus, and is the most common strategy among surgeons. Postoperative rehabilitation of individuals who have had meniscectomies is an important phase of recovery and return to sport, work, and daily life.

We have developed and validated a new rehabilitation protocol which incorporates the knowledge and motivation of physiotherapists and needs and preferences of patients in order to reach meaningful outcomes. Based on the findings of phase II of this study, the protocol showed significant improvement in two of the most important outcomes of knee joint rehabilitation: joint range of motion (ROM) and quadriceps/hamstring strength. Our final protocol includes detailed instructions that a physiotherapist should be able to follow with patients who have undergone partial meniscectomy starting from the third day post-surgery until 8 weeks post-surgery. The protocol is clear, easy, and applicable in rehabilitation settings. However, we expect more refinement and updates to our protocol by other researchers for successful rehabilitation of knee joint functions after partial meniscectomy.

STUDY REGISTRATION

The current study is a part of a Master's thesis (specialty No. 1-88 01 03). This work was registered and conducted within the framework of the topic (1.2.11 НИР, 2006-2010) of the department of Physical Rehabilitation, Belarusian State University of Physical Culture, and in accordance to legislations and regulations of the research work in the Republic of Belarus. Thus, all ethical approvals and trial registration was done locally with the regulatory bodies.

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DISCLOSURE STATEMENT

The authors report no conflicts of interest. The authors alone are responsible for the content, preparation, and writing of this article.

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