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Efficacy and Safety of Remote Physical Rehabilitation in Patients with Hip or Knee Replacement: a Prospective Randomized Comparative Study

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ABSTRACT

INTRODUCTION. An urgent problem of medical rehabilitation is the loss of results that were achieved at various stages due to the interruption of the recovery process and the absence of patients' classes at home after discharge from a medical institution. In this regard, at the third stage of medical rehabilitation, the remote (telemedicine) form of rehabilitation assistance is of particular importance, which has broad prospects for development due to the emergence of new information technologies that allow for active communication between a medical professional and a patient. Nevertheless, the issues of the effectiveness and safety of remote physical rehabilitation remain insufficiently studied, and therefore it is necessary to conduct randomized comparative trials with the analysis of long-term results.

AIM. Evaluation of the effectiveness and safety of the remote physical rehabilitation (RPR) model for a group of patients who have undergone hip (HR) or knee (KR) replacement, the study of patient adherence, as well as the selection of the most informative evaluation tools.

MATERIALS AND METHODS. The study included 30 patients aged 30 to 75 years who underwent HR or KR. The study participants were distributed by the envelope method into groups for remote rehabilitation in addition to routine clinical practice of providing medical rehabilitation (RPR group) or conducting only routine medical rehabilitation (comparison group), including daily independent physical exercises at home, mastered during inpatient medical rehabilitation, lifestyle modification, taking nonsteroidal anti-inflammatory drugs with the development of pain syndrome. An assessment of the effectiveness and safety of rehabilitation measures was carried out, including an analysis of physical examination data, vital signs, as well as data from various scales, tests and questionnaires (the 10-point visual-analog scale (VAS), the Timed 25-Foot Walk (T25-FW), the "Timed Up and Go Test", the Berg Balance Scale (BBS), the Western Ontario and McMaster University Osteoarthritis Index (WOMAC)).

RESULTS AND DISCUSSION. 14 patients were randomized to the remote physical rehabilitation group (49.6 ± 12.4 years) and 16 to the comparison group (57.8 ± 11.2 years). Participation in the study was completed by 10 patients from the RPR group and all 16 patients in the comparison group. Comparing the results of rehabilitation between the groups 1 month after the inclusion of participants in the study revealed a more pronounced statistically significant improvement in the functional profile of the patient on the T25-FW ($p < 0.0001$), the "Timed Up and Go Test" ($p = 0.0064$), the Berg Balance Scale ($p = 0.0008$) and WOMAC ($p < 0.0001$) in group of RPR. The "Timed Up and Go Test", the visual analog scale and the WOMAC were selected based on the results obtained for further practical work. The most significant predictors of premature termination of RPR were older age (χ^2 16.75, $p < 0.0001$), pensioner status (χ^2 11.75, $p = 0.0006$) and residence in the region (χ^2 11.75, $p = 0.0006$). The analysis of adverse events showed that 4 patients in the RPR group and 6 in the comparison group had a periodic increase in pain syndrome in the operated limb.

CONCLUSION. The results obtained demonstrate that of patients who have undergone hip or knee replacement is safe and effective in restoring functional mobility, reducing the risk of falls and the severity of pain syndrome, and increases adherence to physical exercises. The main limitations in the practical use of remote physical rehabilitation are related to the availability of high-speed Internet and the skills of using Internet portals.

KEYWORDS: telemedicine, remote physical rehabilitation, total joint replacement, hip joint, knee joint.

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Эффективность и безопасность дистанционной физической реабилитации у пациентов с эндопротезированием тазобедренного или коленного сустава: проспективное рандомизированное сравнительное исследование

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РЕЗЮМЕ

ВВЕДЕНИЕ. Прерывание восстановительного процесса и отсутствие занятий пациентов в домашних условиях после выписки из лечебного учреждения приводит к потере результатов, достигнутых на различных этапах медицинской реабилитации. В связи с этим особое значение приобретает дистанционная (телемедицинская) форма оказания реабилитационной помощи, имеющая широкие перспективы развития в связи появлением новых информационных технологий, позволяющих реализовывать активную коммуникацию между медицинским работником и пациентом. Тем не менее, вопросы эффективности и безопасности дистанционной реабилитации остаются недостаточно изученными, в связи с чем необходимо проведение рандомизированных сравнительных исследований с использованием наиболее информативных оценочных инструментов.

ЦЕЛЬ. Оценка эффективности и безопасности модели дистанционной физической реабилитации (ДФР) для группы пациентов, перенесших эндопротезирование (ЭП) тазобедренного (ТБС) или коленного (КС) сустава, изучение приверженности пациентов, а также отбор наиболее информативных оценочных инструментов.

МАТЕРИАЛЫ И МЕТОДЫ. В исследование включено 30 пациентов от 30 до 75 лет, перенесших эндопротезирование тазобедренного или коленного сустава. Участники исследования распределялись методом конвертов в группы для проведения ДФР в дополнение к рутинной клинической практике оказания медицинской реабилитации (группа ДФР) или проведения только рутинной медицинской реабилитации (группа сравнения), включающей ежедневные самостоятельные занятия физическими упражнениями в домашних условиях, освоенные во время стационарной медицинской реабилитации, модификацию образа жизни, прием нестероидных противовоспалительных препаратов при развитии болевого синдрома. Выполнена оценка эффективности и безопасности реабилитационных мероприятий, включающая анализ данных физикального обследования, показателей жизнедеятельности, а также данных различных шкал, тестов и опросников (10-балльная визуально-аналоговая шкала (ВАШ), тест времени прохождения 7,62 м (Timed 25-Foot Walk, T25-FW), тест «встань и иди», шкала равновесия Берга (Berg Balance Scale, BBS), функциональный индекс оценки остеоартроза коленного и/или тазобедренного сустава (Western Ontario and McMaster University Osteoarthritis Index, WOMAC)).

РЕЗУЛЬТАТЫ И ОБСУЖДЕНИЕ. 14 пациентов рандомизированы в группу ДФР (49,6 ± 12,4 года) и 16 в группу сравнения (57,8 ± 11,2 года). Участие в исследовании завершили 10 пациентов из группы ДФР и все 16 пациентов в группе сравнения. При сравнении результатов реабилитации между группами спустя 1 месяц после включения участников в исследование выявлено более выраженное статистически значимое улучшение функционального профиля пациента по T25-FW ($p < 0,0001$), тесту «встань и иди» ($p = 0,0064$), шкале Берга ($p = 0,0008$) и WOMAC ($p < 0,0001$) в группе ДФР. На основании полученных результатов для дальнейшей практической работы были отобраны тест «встань и иди», визуально-аналоговая шкала и WOMAC. Наиболее значимыми предикторами преждевременного прерывания ДФР являлись более старший возраст ($\chi2$ 16,75, $p < 0,0001$), статус пенсионера ($\chi2$ 11,75, $p = 0,0006$) и проживание в области ($\chi2$ 11,75, $p = 0,0006$). Анализ нежелательных явлений показал, что у 4 пациентов в группе ДФР и 6 в группе сравнения отмечалось периодическое усиление болевого синдрома в оперированной конечности.

ЗАКЛЮЧЕНИЕ. Полученные результаты демонстрируют, что дистанционная физическая реабилитация пациентов, перенесших эндопротезирование тазобедренного или коленного сустава, безопасна и эффективна в отношении восстановления функциональной мобильности, снижения риска падений и выраженности болевого синдрома, позволяет повысить приверженность к занятиям физическими упражнениями. Основные ограничения при практическом использовании дистанционной физической реабилитации связаны с доступностью высокоскоростного интернета и навыками использования интернет-порталов.

КЛЮЧЕВЫЕ СЛОВА: телемедицина, дистанционная физическая реабилитация, эндопротезирование, тазобедренный сустав, коленный сустав, медицинская реабилитации.

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INTRODUCTION

In the last decade, great changes have been taking place in the system of organization of medical rehabilitation (MR) in Russia: a new specialty «doctor of physical and rehabilitation medicine» has appeared, a clear three-stage system of routing of rehabilitation patients has been established, and the corresponding regulatory and legal framework has been developed [1, 2]. However, one of the problems is the loss of the results achieved at different stages of MR due to the patients' discontinuation of home-based activities after discharge from the treatment facility [3]. This problem is associated with a significant burden on the rehabilitation care system due to the large number of people in need of MR in Russia (more than 6 million people) and staff shortages [1, 2]. The availability of rehabilitation care at home may also be reduced due to geographical peculiarities (long distances and low population density) of some regions of our country [4].

In this regard, the remote form of organizing rehabilitation at the third stage of rehabilitation care is of particular importance, which has prospects for development due to the emergence of new information technologies that enable the implementation of active communication between the healthcare worker and the patient [5]. Remote MR is one of the areas of telemedicine and is a system of interactive rehabilitation process with the use of information and telecommunication technologies that help to restore health, functional state and working capacity of patients [1, 6]. In both developed and developing countries, there are still obstacles to the introduction of telemedicine, which unnecessarily slows down its spread. In the Russian Federation, remote rehabilitation currently exists only in some rehabilitation institutions; there are no unified approaches to its organization [7, 8]. In addition, the efficacy and safety of remote rehabilitation remain poorly studied, and therefore randomized comparative studies with analysis of long-term outcomes are needed.

Since February 2023 the Institute of traumatology and orthopaedics of the University Clinic of FSBEI HE «Privolzhsky Research Medical University» of the Ministry of Health of Russia (Nizhny Novgorod) has been implementing the project «Development of a model of remote rehabilitation care for persons with motor disorders within the third stage of the MR using a digital rehabilitation platform» within the frames of Privolzhsky Research Medical University «Priority-2030» Development programme. The aim of the project is to create a model of remote physical rehabilitation (RPR) for persons with motor impairments due to a hip or a knee joint replacement and to introduce this model into the practice of rehabilitation institutions of the Russian Federation. The choice of the DFR model is not accidental: on the one hand, kinesiotherapy is the basis for rehabilitation of patients who have undergone a hip or a knee joint replacement, on the other hand, the number of physical rehabilitation specialists is still insufficient to meet the demand for full-time rehabilitation of patients with this profile at stage III. The relevance of this project is particularly emphasized by the fact that approximately 500,000 hip and knee replacements are performed worldwide each year and the need for these operations is constantly increasing [9–12]. According to the report of «National Medical Research Centre for Traumatology and Orthopaedics named after N. N. Priorov», 76,849 knee replacements and 54,720 knee replacements were performed in Russia in 2019, the increase in the number of endoprosthetic surgeries during 2017–2019 was 16.2 % [9, 13]. Among 85 regions of the Russian Federation, Nizhny Novgorod region ranks the 7th in the number of primary hip replacements (7.4 per 10,000 population) and the 16th in the number of knee replacements (3.3 per 10,000 people) [9, 13]. The growing number of hip and knee replacements increases the relevance of remote approaches to medical rehabilitation of this category of patients [14].

When planning the work, it was decided to use the existing portal of remote rehabilitation «Steps Reabil» («Digital Technologies Centre» Ltd.), having created a separate block for it regarding DPR of patients with hip or knee replacements. The «Steps Reabil» Internet platform combines the best practices of other similar Internet resources and is already being actively used in leading medical institutions of the Russian Federation, such as the Pirogov National Medical and Surgical Centre, Federal State Autonomous Institution «National Medical Research and Development Centre «Treatment and Rehabilitation Centre» of the Ministry of Health of Russia, FSBI Federal Centre for Brain and Neurotechnology of FMBA of Russia and others. This interactive platform contains more than 150,000 combinations of exercises for motor, speech and psychological rehabilitation, with a video library of exercises and software placed in a «cloud» storage. Access to personal programmes (video files) is provided through the web-interface of any device: computer, laptop, tablet, smartphone, virtual reality headset and smart TV (TV set with integrated internet and interactive functions). The functionality of the platform provides for the doctor's ability to create a rehabilitation plan and exercise schedule, maintain feedback with the patient via e-mail, chat and video, and evaluate the effectiveness of MR using tests and questionnaires. It is also possible to integrate the DPR platform into the medical information system of the institution. Connecting participants to the platform and conducting remote training on the platform is possible within a day [5, 8, 15].

Under the agreement between FSBEI HE «Privolzhsky Research Medical University» of the Ministry of Health of Russia and «Digital Technologies Centre» LLC on the basis of «STEPS REABIL» platform a block/module «Orthopaedics» (https://pimunn.stepsreabil.com/) was created, which contains 522 video clips with demonstration of physical exercises used at different stages of MR of patients after hip or knee replacement, as well as a set of evaluation tools to monitor the effectiveness of MR. The posted videos were filmed and edited by specialists of «Privolzhsky Research Medical University», who have many years of experience in physical rehabilitation of patients who have undergone hip or knee replacement. The physical exercises presented in the video library have different levels of difficulty and are aimed at restoring muscle strength of key muscles, balance training, prevention of contractures, restoration of normal walking pattern, improvement of functional mobility of patients. Video clips were «tagged», i.e. each video clip with demonstration of a particular physical exercise was assigned keywords, according to which the specialist selects exercises for a particular patient. The video library is tagged by the position in which the exercise is performed (on the back, stomach, on the side, palm-knee, etc.), by the body part involved (hip, knee, buttock, leg, etc.), by the training focus (coordination, walking, motor skills, etc.), by the level of difficulty and aspect, and by the gymnastic equipment used (block, wand, elastic strap, ball, Swedish wall, etc.) (Figure 1). When creating a set of videos for a particular patient, the «Steps Reabil» portal allows you to specify the number of repetitions, the duration of the exercise and the purpose of the exercise.

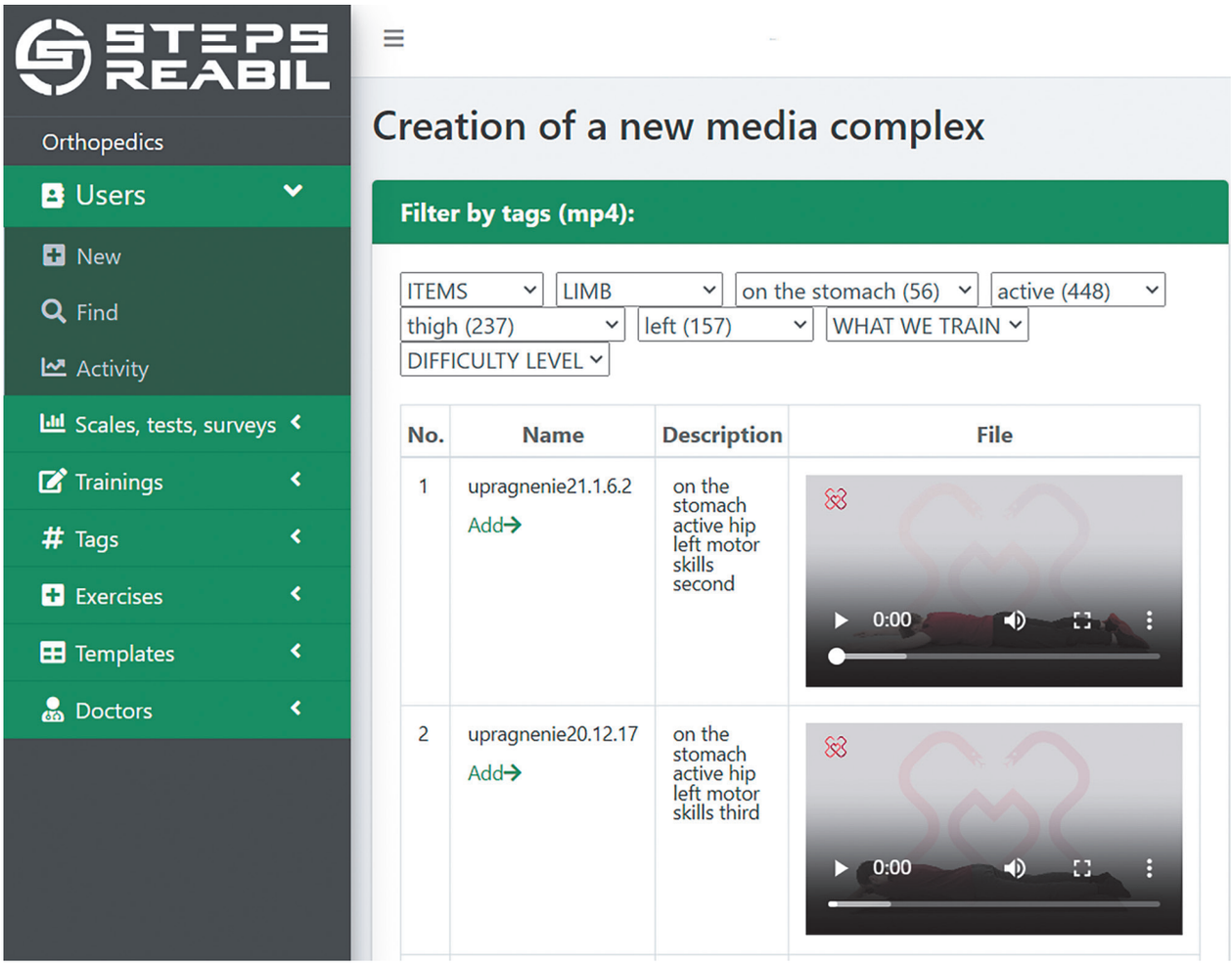

Fig. 1. The interface of the «Ortopediya» block of Privolzhsky Research Medical University on the portal of remote rehabilitation «Steps Reabil» in the mode of selecting a set of videos by tags

The set of assessment tools was formed in accordance with clinical guidelines for the management of patients with coxarthrosis and gonarthrosis and includes various tests, scales and questionnaires to assess the severity of pain syndrome, functional mobility and risk of falls [11, 12]. In the future, as the collection of video library with exercises designed for rehabilitation of patients with injuries and diseases of the spine, hand, foot, shoulder, elbow, wrist joints and other orthopaedic pathologies grows, it is planned to add appropriate tests and questionnaires to assess the effectiveness of rehabilitation. The portal also offers an opportunity to place information materials that contain useful information for patients regarding MR.

AIM

To assess the effectiveness and safety of the DFR model for a cohort of patients who have had a hip or a knee replacement, to study patient adherence, and to select the most informative assessment tools.

MATERIALS AND METHODS

We have developed and received approval in the local ethical committee of FSBEI HE «Privolzhsky Research Medical University» of the Ministry of Health of Russia (extract from minutes No. 04 of 17 March 2023) the protocol of a prospective randomized comparative study in a group of patients who underwent a hip or a knee replacement, using the «Orthopaedics» block of the digital rehabilitation platform for adults and children «Steps Reabil». The duration of participation in the study is 2 months per participant, with 4 face-to-face visits to a physical and rehabilitation medicine or physical therapy physician (screening, randomization, visit 4 and 8 weeks after randomization). The total estimated duration of the study, which is planned to include 80 patients, will be 15 months. At the screening visit, the patient is invited to participate in the study and provided with all relevant information. During this visit, inclusion/exclusion criteria will be assessed, informed consent will be signed, demographic and medical history will be collected, physical examination will be performed, and baseline vital signs will be measured. Randomization is done by the closed-envelope method within 30 days after the screening visit and includes reassessment of inclusion/exclusion criteria, physical examination, measurement of vital signs, assessment of pain severity, functional mobility and risk of falls using various tests, scales and questionnaires, followed by the closed-envelope method placement of patients into one of the groups.

Inclusion Criteria

Informed consent signed by the participant before any procedures related to the study; participant's age from 30 to 75 years inclusive; a scheduled hip or knee replacement; documentation of the first and second stages of MR after endoprosthetics; absence of complications during surgery and in the postoperative period; the patient's fluency in Russian; the patient's ability to access the Internet from a personal computer, laptop, tablet, smartphone.

Exclusion Criteria

Current or past significant co-morbidities in the opinion of the investigator that may adversely affect participation in this study; persistent chronic or active recurrent infection with a need for antibiotic, antiviral or antifungal treatment; any malignancy within 5 years prior to the screening visit; serious mental disorder e.g. bipolar disorder, dementia; short life expectancy due to pre-existing condition(s), in the opinion of the treating physician (rehabilitation physician).

The study participants, according to the protocol, were placed in groups at the third stage of rehabilitation in a 1:1 ratio to receive DPR in addition to routine clinical practice of MR (DPR group) or routine MR alone (comparison group). Routine MR includes daily independent physical exercises at home, learnt during inpatient treatment in the second stage of MR, lifestyle modification, taking non-steroidal anti-inflammatory drugs in case of pain syndrome development. The patients in the DPR group are advised that there is no need to do any physical activities at home other than those presented on the DPR portal. Patients in the comparison group enter the date, start and end times of exercise and adverse events in the diary for self-monitoring and further compliance analysis. In the DPR group, information about the fact and duration of exercise can be automatically accessed by the physician in the "Activity" section of the DPR portal.

The patients randomized to the DPR group are provided with instructions on how to use the «Orthopaedics» block of the «Steps Reabil» portal and a personal account and the peculiarities of DPR are explained. A link is then sent to the study participant from the DPR group by e-mail, which the patient uses to access the personal account to undergo DPR within 1 month. The DPR programme, which includes a set of videos with exercise demonstrations, is formed for each individual patient individually, taking into account his or her individual functional capabilities and comorbid background. During the randomization visit, the physician explains to the patient the substance of the exercises, their duration and frequency, as well as the necessary conditions for their performance. Subsequently, a physical rehabilitation specialist interacts with the patient for the duration of DPR, who can make changes to the distance rehabilitation programme. The patient performs DPR exercises independently for 1 month daily for an average of 20–40 minutes. 2 times a day. The duration and frequency of exercises are strictly individual, and may be modified by the physical rehabilitation specialist depending on the patient's well-being and recovery progress. According to the protocol, absences due to patient's ill health or family circumstances are allowed, but not more than 5 consecutive days or more than 15 days per month in total. All the patient's activity on the «Steps Reabil» portal (videos watched, tests, scales and questionnaires completed) is monitored in real time by the physical rehabilitation specialist and adjustments can be made. If necessary, the patient can contact the physical rehabilitation specialist via chat on the DPR portal or bya phone call.

Clinical Assessment of the Effectiveness of Rehabilitation Measures

According to the protocol, clinical assessment of the rehabilitation effectiveness in both groups is carried out during face-to-face visits (randomization, completion and follow-up visits) and includes analysis of physical examination data, vital signs, and data from various scales, tests and questionnaires. Within the frames of the approbation we used a 10-point visual analogue scale (VAS), the Timed 25-Foot Walk (T25-FW), the «Timed Up and Go» test, the Berg Balance Scale (BBS), the Western Ontario and McMaster University Osteoarthritis Index

Table 1. Clinical and demographic data of subjects

Characteristics	RPR Group, *n* = 14	Comparison Group, *n* = 16	*p*
Age, years	49.6 ± 12.4	57.8 ± 11.2	0.0677*
Gender, male	6 (43 %)	8 (50 %)	0.7005 χ^2 Pearson's chi-squared test 0.73 Fisher's exact test
Operated joint, HJ/KJ	11(79 %)/3(21 %)	11(69 %)/5(31 %)	0.5507 χ^2 Pearson's chi-squared test 0.6887 Fisher's exact test
BMI, kg/m²	28.5 [25.5; 32.5]	27.2 [25.8; 31.9]	0.6177**
Obesity	5(36 %)	4(25 %)	0.5299 χ^2 Pearson's chi-squared test 0.6943 Fisher's exact test
Education level, secondary/ higher	6(43 %)/8(57 %)	8(50 %)/8(50 %)	0.7005 χ^2 Pearson's chi-squared test 0.7300 Fisher's exact test
Social status, working/not working	9(64 %)/5(36 %)	8(50 %)/8(50 %)	0.4386 χ^2 Pearson's chi-squared test 0.4837 Fisher's exact test
Type 2 diabetes mellitus	2(14 %)	6(38 %)	0.1584 χ^2 Pearson's chi-squared test 0.2255 Fisher's exact test
Hypertension	7(50 %)	9(56 %)	0.7364 χ^2 Pearson's chi-squared test 1.0 Fisher's exact test

Note: *RPR — remote physical rehabilitation; HJ — hip joint, KJ — knee joint; BMI — body mass index; * — Independent samples t-test; ** — Mann-Whitney test.*

(WOMAC). Based on the results of the platform approbation, the most informative and non-duplicative tests were selected.

Statistical processing

Of the findings was performed using MedCalc Statistical Software and Microsoft Office Excel, 2021. The normality of distribution of quantitative characteristics is checked using the Shapiro-Wilk test. Quantitative data are presented in the form of arithmetic mean and standard deviation in case of normal distribution of indicators or in the form of medians and borders of interquartile range in case of distribution of indicators different from normal; qualitative indicators — in the form of absolute values and percentages; n — volume of the analyzed group, p — value of statistical significance of differences. Statistical comparison of mean values in the group is performed using methods of parametric and nonparametric statistics: paired Student's t-test and Wilcoxon's test, respectively (for related samples), Student's test and Mann-Whitney's test, respectively (for unrelated samples). The Pearson χ2 test for contingency tables is used to test the hypothesis of the relationship between qualitative and ordinal characteristics. If there is a risk of bias in the results obtained using Pearson's χ2 test for contingency tables, Fisher's exact test is used to test the null hypothesis by pairwise comparison of the data of the analyzed groups in four-field tables. Analysis of the relationship (correlation) between two quantitative characteristics is carried out by the Spearman rank correlation method (r). The critical value of the significance level is assumed to be 5 % ($p \leq 0.05$).

RESULTS AND DISCUSSION

From May 2023, 30 patients who had undergone hip or knee replacement were included in the study. Of these, 14 were randomized to the DPR group and 16 to the comparison group. There were no differences in the main clinical and demographic characteristics of the patients at the time of inclusion into the study (Table 1). The patients in the comparison group were independently engaged in gymnastics at home, using physical exercises learnt at the inpatient stage of DPR. 7 patients in the DPR group and 6 in the comparison group took periodically non-steroidal anti-inflammatory drugs for pain. 2 patients from the DPR group used a magnetic therapy device at home, 1 patient from the comparison group performed kinesiotaping of the knee joint in a private clinic, and 2 other patients from the comparison group occasionally used an Orthosis on the knee joint of the operated limb for pain.

When comparing baseline scores of tests, scales and questionnaires (T25-FW, «Timed Up and Go» test, VAS, BBS and WOMAC) between groups at the time of inclusion of participants in the study, no statistically significant deviations were found.

Ten patients in the DPR group and all 16 patients in the comparison group completed the study according to the protocol. 4 patients in the DPR group terminated their participation early due to absenteeism or refusal to participate. In the DPR group (n = 10), the mean number of days per month that a patient engaged in physical activity using the portal was 23.7 ± 3 days and the duration per session was 33.2 ± 5.3 minutes. In the comparison group, the mean number of exercise sessions that participants performed at home independently during the month was 17.7 ± 3.6 days and the duration was 25.1 ± 6.1 minutes, which was statistically significantly less (p = 0.0002, p = 0.0023, respectively) than in the DPR group.

Comparison of results in the DPR group (n = 10) 1 month after DPR sessions revealed statistically significant improvement in T25-FW (p = 0.0487), "Timed Up and Go" test (p = 0.0132), VAS (p = 0.0090), WOMAC (p = 0.0003) and BBS (p = 0.0455), confirming improvement in the patient's functional profile and reduction in pain severity. The comparison group also showed improvement after 1 month of routine MR as part of the third phase, but only in VAS (p = 0.0458) and WOMAC (p = 0.0415); no statistically significant improvements were found in other

Table 2. Comparison of indicators of questionnaires/scales inside the groups

Scale / test / questionnaire	The average value of the indicator			
	RPR Group		Comparison Group	
	Initial indicators, n = 14	Indicators after 1 month, n = 10	Initial indicators, n = 16	Indicators after 1 month, n = 16
T25-FW, sec	7 ± 1.2	6.1 ± 0.5	7.6 ± 1.0	7.6 ± 0.8
p	**0.0487***		0.6795*	
«Timed up and go» test, sec	8.5 ± 2	7 ± 0.9	8.8 ± 1.5	8.6 ± 1.5
p	**0.0132***		0.2419*	
VAS, score	5 [4; 5]	2 [1; 2]	3 [1.5; 4]	2 [1.5; 3]
	0.0090**		**0.0458****	
BBS, score	43 ± 6.5	47.5 ± 3.7	42.3 ± 4.9	41.1 ± 4.3
p	**0.0455***		0.0983*	
WOMAC, score	36.4 ± 6.2	18.9 ± 7.6	34.8 ± 5.9	32.9 ± 4.7
p	**0.0003***		**0.0415***	

Note: *RPR — remote physical rehabilitation; BBS — Berg Balance Scale; WOMAC — Western Ontario and McMaster University Osteoarthritis Index; * — Paired samples t-test; ** — Wilcoxon test.*

tests, scales and questionnaires (T25-FW, the «Timed Up and Go» test and BBS) (Table 2).

Furthermore, when comparing rehabilitation outcomes between groups 1 month after inclusion of participants in the study, a greater statistically significant improvement in T25-FW ($p < 0.0001$), «Timed Up and Go» test ($p = 0.0064$), BBS ($p = 0.0008$) and WOMAC ($p < 0.0001$) scales was found in the DPR group, suggesting greater effectiveness of DPR in addition to routine MR compared to routine MR rehabilitation care alone as part of the third phase of the MR program.

Correlation analyses of the results of examinations performed 1 month after the inclusion of participants in both groups in the study showed a positive correlation between the «Timed Up and Go» and T25-FW tests ($r = 0.501$, $p = 0.0482$), both of which assess functional mobility [16, 17], and the «Timed Up and Go» and BBS tests ($r = 0.623$, $p = 0.0100$), which assess the risk of falls [16, 18]. These results indicate that it is acceptable to use only the «Timed Up and Go» test to assess the risk of falls and functional mobility. Based on these results, the «Timed Up and Go» test, VAS and WOMAC were selected for further practical work.

Special attention was paid to the problems encountered during DPR, namely compliance issues of DPR patients. The main problem was the availability and speed of the Internet. Some participants ($n = 5$) living in the districts of Nizhny Novgorod region noted that despite their desire to perform the exercises, they could not do so due to temporary interruptions in the operation of their Internet provider, i.e. the company providing the client's access to the Internet. Four patients missed more than 5 consecutive days or refused to complete the DPR due to technical reasons related to the internet. The likely factors influencing the refusal or inability to use DPR on a regular basis were analyzed. The factors analyzed included the participant's education level (primary/secondary/higher education), social status (working/not working), age, and place of residence (city/region). Univariate regression analysis showed that older age (χ^2 16.75, $p < 0.0001$), pensioner status (χ^2 11.75, $p = 0.0006$) and residence in the region (χ^2 11.75, $p = 0.0006$) were more significant predictors of premature DPR interruption, which is probably related to low skills in modern mobile and communication devices, as well as low internet speed and internet provider outages.

The analysis of adverse events showed that 4 patients in the DPR group and 6 in the comparison group had periodic increase of pain syndrome in the operated limb during the first days of physical rehabilitation. After changing the intensity of the exercises, the pain syndrome regressed or the pain severity significantly decreased. No other adverse events related to the study were detected.

Limitations of the study and recommendations for further studies

The presented findings are preliminary, as they were obtained using a small sampling. Continuation of the study with the inclusion of a larger number of participants will allow obtaining more accurate data necessary to draw correct conclusions.

CONCLUSION

The remote form of rehabilitation organization has great prospects for development due to the emergence of new information technologies that allow for active communication between a healthcare professional and a patient. We have developed a model of remote physical rehabilitation of patients, which is based on the principle of continuity and consistency of rehabilitation care. The model involves remote provision of individualized exercise complexes to the patient, presented in the form of video clips, as well as the possibility of online control over the progress of the patient's condition. The approbation involving 30 patients who underwent replacement of large joints of the lower limb demonstrated that the remote form of physical rehabilitation in this category of patients is safe and effective in restoring functional mobility, reducing the risk of falls and the severity of pain syndrome, and helps to increase adherence to physical exercise. The main limitations in the practical use of remote physical rehabilitation are related to the availability of high-speed internet and skills in using internet portals. It is planned to continue this study with the inclusion of more participants and evaluation of long-term results, which will provide the accurate findings needed to draw correct conclusions.

Further development of the portal of remote medical rehabilitation for this category of patients, in addition to improving the shortcomings identified in the process of approbation, provides for the implementation of a multidisciplinary approach (including sessions with an occupational therapist and a medical psychologist).

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