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Assessment of Hip Joint Function and Limb Load in Patients after Cementless Hip Arthroplasty During 14-day Rehabilitation

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Abstract

Background: *Arthoplasty is a surgical procedure consisting in replacing a natural joint altered by the disease process with an artificial joint. This surgery allows you to restore the lost function of the hip joint. Comprehensive rehabilitation plays an essential role after surgery.*

Objectives: *The aim of the study was to assess the impact of rehabilitation on patients on the 1st and 14th day of rehabilitation after cementless hip arthroplasty on the load on the operated limb and to assess the function of the hip joint.*

Material and methods: *The studies were performed on a group of 44 patients with post-surgery rehabilitation.The studies were performed twice: on the 1st and 14th day of rehabilitation. The standardized questionnaires was used: Harris Hip Score and WOMAC. The reaction of ground forces was assessed using the Alpha stabilometric platform.*

Results: *The average point value indicated on the Harris Scale significantly increased in the measurement on the 14th day of rehabilitation by 8.57 ± 6.56 points ($p < 0.001$). On the other hand, the WOMAC Scale showed a decrease in point values in the second measurement by 9.67 ± 6.76 points ($p < 0.001$). A significant increase in the average load on the operated lower limb by 3.68 ± 3.18% was indicated as measured on the 14th day of rehabilitation ($p < 0.001$). The difference between the average load of the right and left limbs in the measurement on the first day of rehabilitation was an average of 9.77%, while on the fourteenth day of rehabilitation the difference between the average load of the right and left limbs decreased to an average of 3.5%.*

Conclusions: *Postsurgery rehabilitation allows to obtain physiological load ranges of the lower limbs, striving for a 50% share in the load of each of the lower limbs. The effectiveness of the implemented rehabilitation is confirmed on the basis of the analysed limb load parameters and the analysis of patients' subjective assessments made using standardized questionnaires.*

Introduction

The hip joint transfers heavy loads thanks to the appropriate structure of bone elements and strong ligaments and muscles. Disorders during movements in the hip joint are often caused by degenerative changes. They lead to disorders in the functioning of not only the lower limbs but also the spine and, consequently, the whole organism [1].

Osteoarthritis is one of the most common diseases and is a significant social and economic problem, especially in an ageing society. Functional disorders, including problems with gait, reduce the quality of life and are the main cause of a significant reduction in fitness in the elderly population [1, 2, 3].

Population ageing causes the incidence of osteoarthritis to increase. Among people over 75 years of age, over 80% of the population suffers from it [1]. This has become the reason for naming it a civilization disease. The changes it causes are characterized by a gradual degradation of the cartilage and the subchondral bone layer. This process may be accompanied by synovitis [1].

The etiology of degenerative changes is not fully understood, but the following factors are considered to increase the risk of developing the disease: age, sex, overweight, genetic factors, overloads, and injuries [4].

As the disease progresses, the patient struggles with increasing pain, stiffness, and limitation of joint mobility. Pain is usually felt in the front part of the thigh, groin, and the knee joint. Initially, it occurs only with movement, but as the disease progresses, it also increases at rest and at night. Secondarily, as a result of the disease, muscle atrophy and contractures, relative shortening of the limb and inflammation of the surrounding soft tissues occur as well [3, 5].

Mobility problems, chronic pain, side effects of long-term pharmacological treatment, and difficulties in performing activities of daily living are often the critical reasons for which a patient decides to withdraw from conservative treatment and undergo surgery. Hip arthroplasty is the last step in the treatment of coxarthrosis, which reduces pain, improves biomechanical conditions of the joint and gait, and enables physical activity, thus having

a positive effect on the quality of life of patients [5, 6, 7, 8]. This surgery consists in replacing the natural joint damaged in the disease process with an artificial joint, i.e., the so-called endoprosthesis [9].

Hip arthroplasty is one of the most common surgical procedures in Europe. In addition, it is a solution for most patients with hip disorders causing chronic discomfort or dysfunction of the hip joint [10, 11]. In Poland, since 2005, the implementation of hip arthroplasty reimbursed from the National Health Fund (NFZ) is reported in CBE (Central Database of Endoprosthesoplasty). According to the CBE data, the implementation of the procedure more than doubled between 2005 and 2019, and hip replacements are performed more often than knee replacements and account for 64% of all arthroplasty [12]. A different tendency is observed, for example, in the USA, where knee arthroplasty prevails [13].

The hip arthroplasty procedure is aimed at improving the quality of life of patients [2, 3, 14, 15] and due to its irreversibility, it is the last stage of coxarthrosis treatment and is considered a treatment of advanced stages of osteoarthritis [5, 9]. In addition, due to the effectiveness of reducing pain and improving the functioning of patients, it is one of the most frequently performed surgical procedures. Due to the ageing of the population and increasing obesity rates, an even greater need for joint arthroplasty should be expected in the coming years [10, 16, 17].

Providing care for a patient undergoing hip arthroplasty requires the involvement of the entire therapeutic team, going beyond the surgery itself. Comprehensive actions are taken to ensure the patient's safety and quick recovery, as well as improvement of the quality of life [10, 18].

Physical rehabilitation is an extremely important element of therapy. The mobilization of the patient both before the surgery and the continuation of physiotherapeutic procedures after the surgery, also at home, significantly affect the pace of recovery and improvement of the quality of life [10, 19]. The physiotherapeutic procedure after hip arthroplasty is very diverse. The rehabilitation program may be individualized depending on the indications for surgery, the surgical technique, the type of implant, the presence of comorbidities, as well as the patient's general health, age, and activity level [19].

Radical surgery should not be delayed and should be performed when the pain is increasing (with no chance of reversing it). Advanced arthrosis always makes it difficult to save the patient's ligament-capsular structures that are responsible for passive stability and proprioception. The fixed pathological stereotype of gait, muscle atrophy, reduced fitness and exercise capacity are the reasons for the extension of the rehabilitation period. These changes most often argue for early intervention. The surgery relieves pain and helps to regain the lost function of the joint. This is possible only through conscientious and regular rehabilitation and preparation of an exercise program selected individually for each patient. It should be supported with physical therapy [5, 20, 21].

The complexity of the problems that affect patients with degenerative changes in the hip joint is a significant challenge for health protection and the medical personnel who take care of the patient. The joint work of the members of the rehabilitation team allows for the creation, implementation, and monitoring of an individual rehabilitation program for each patient, considering his/her needs and possibilities [22]. Actions must be aimed at combating pain, as well as at adaptation to the progressive nature of the disease, in order to maintain physical, social, and professional fitness as long as possible [23].

Properly implemented pre- and post-surgery rehabilitation have a very important role. They have an impact on the improvement of efficiency in the performance of basic activities of daily living, better well-being, and higher quality of life [23, 24].

The object of the study was the impact of cementless hip arthroplasty on the functions of the joint under surgery.

Purpose of the study

The aim of the study was to assess the impact of rehabilitation on patients on the 1st and 14th day of rehabilitation after cementless hip arthroplasty on the load on the operated limb and to assess the function of the hip joint.

Materials and methods

Study group

The study was performed on a group of 44 patients staying at the Rehabilitation Department of the Holy Family High Speciality Hospital in Rudna Mala, Poland, including 25 women (56.8%) and 19 men (43.2%). The average age of the subjects was 69.18 ± 9.81 years old. The average BMI was 27.62 ± 3.99 kg/m^2. In the case of 23% of the subjects, this indicator was within the normal range, 57% of the subjects were overweight, and 20% were obese. Due to the number of surgeries, all patients are distinguished by a primary prosthesis put on for the first time, without complications (Table 1)

Table 1. General characteristics of the study group of the respondents

Characteristic	n	%
Place of residence (n – 44) • village / city	25 / 19	56.8 / 43.2
Education (n – 44) • primary / vocational / secondary / higher	4 / 13 / 22 / 5	9.1 / 29.5 / 50.0 / 11.4
Employment status (n – 44) • works / white collar / retirement / does not work	4 / 5 / 32 / 3	9.1 / 11.4 / 72.7 / 4.5
BMI • normal (18.5–24.99) / overweight (25.0–29.99) / obese (>30.0)	10 / 25 / 9	22.7 / 56.8 / 20.5
Reason for endoprosthesis implantation (n – 44) • Osteoarthritis / Joint injury / Birth defects	39 / 3 / 2	88.6 / 6.8 / 4.5
Dominant limb (n – 44) • Right / left	29 / 15	65.9 / 34.1
Limb in which the prosthesis is located • Right / left / right and left	24 / 12 / 8	54.5 / 27.3 / 18.2

Variable	Me	Q1
Age (n – 44) [years]	71.50	64.50
BMI (n – 44) [kg/m^2]	26.79	25.17

N – number of observation; % – percent; M – average; SD – standard deviation; Me – median; Reference – minimum to maximum; Q1 – lower quartile; Q3 – upper quartile

The patients were subjected to the rehabilitation process in the period from 3 to 24 months from the implantation of the joint endoprosthesis. The time that elapsed from the endoprosthesis procedure to the day of the study was, on average, 5.38 ± 3.11 months for patients operated on the right side and 6.06 ± 2.86 months for patients operated on the left side.

In the study group, eight people had endoprostheses implanted in both hip joints. The time that elapsed from the implantation of the primary (placed for the first time without complications) endoprosthesis to the day of the study was on average 32.33 months ± 25.44 months in the case of patients operated on the right side and 15 months ± 4.24 months in the case of patients operated on the left side.

The performed study showed that none of the patients benefited from pre-surgery rehabilitation, while all respondents declared that after leaving the hospital, they followed the recommendations provided by the physiotherapist.

Model of rehabilitation

The patients' rehabilitation treatment included five procedures:

1. Rail – Continuous Passive Motion (CPM).
2. Isometric exercises of the lower limb muscles.
3. Learning to walk (usually on a treadmill) with step length analysis.
4. Kinesiotherapy – guided or other exercises depending on the period.
5. Cryotherapy.

The rehabilitation program was conducted for 1 hour, 5 times a week.

The inclusion criteria were: age of respondents over 18 years, cementless arthroplasty in the period from 3 to 24 months, no postoperative complications, no other contraindications to rehabilitation, ability to maintain an upright position without any aid or physical assistance, and absence of dementia or other cognitive impairments.

The basis for the patient's inclusion in the therapeutic process was the medical qualification. The entire rehabilitation process was an element of comprehensive rehabilitation of patients undergoing hip arthroplasty, staying at the rehabilitation ward.

Standardized questionnaire: WOMAC – HIP, Harris Hip and ALFA platform

The data were collected using an original questionnaire supplemented with standardized tools to assess the quality of life of patients after alloplastic surgery: the WOMAC-HIP questionnaire used to monitor the progress of rehabilitation treatment and the Harris Hip Score (HHS) for the functional assessment of the hip joint. The HHS consists of 4 subscales: pain (44 points), function (47 points), no deformity (4 points), and range of motion (5 points). In the case of the Harris Hip Score, 0–100 points can be obtained, where obtaining the total sum of points above 90 means very good functionality of the hip joint, 80–89 – good, 70–79 – sufficient, while values < 70 indicate poor functionality [25]. The WOMAC (*Western Ontario and McMaster Osteoarthritis Index*) is a multidimensional assessment tool and self-assessment of disability of patients with the degenerative disease, especially of the knee and hip joints. The questionnaire uses 24 parameters: discomfort while walking/lying/sitting/getting up, stiffness in the morning and during the day, difficulty in walking/sitting/bending/climbing stairs/putting on socks, etc. These are divided into three groups: pain, stiffness, and function. Each of the 24 questions has a 5-point response scale (from 0 to 4 points), depending on the degree of problems with performing a given task activities. The results are obtained for each of the three components: pain – 0–20 points, stiffness – 0–8 points, function – 0–68 points that together yield the global score 0–96 points. The lower the number of points the patient scores, the better his/her functional condition is. The more points, the greater the symptoms and the poorer the functioning [26]. In addition, lower limb loading was assessed with the use of the ALFA stabilometric platform in all subjects.

The ALFA platform allows assessing as well as carrying out balance training for orthopedic and neurological patients. It assesses static and dynamic parameters related to maintaining balance in conditions of a stable ground. The platform measures 550 x 550 x 80 mm and weighs 27 kg. The platform works with the software, allowing for the assessment of rehabilitation

progress, it also enables the generation of reports for a given patient. The sampling rate was set to 120Hz [27].

Methodology of the study

The platform was placed on a stable surface and calibrated in accordance with the manufacturer's recommendations. Before the start of the tests, the patients remained in a sitting position for 5 minutes.

In order to verify the effectiveness of rehabilitation in a given patient, each patient was tested twice on the ALFA platform: on the 1st and 14th day of the rehabilitation process. Before the first trial, the outline of each participant's feet was recorded to ensure consistent foot position between trials The test involved standing with both feet without shoes on the ALFA platform. The test duration was 30 seconds. Before the test, the subject was instructed in detail about the course and proper performance of the test: free standing, without moving the head and upper limbs, looking straight ahead. During the study, tests were performed using the ALFA platform, only the subject and the person performing the study were present in the room. In addition, to limit the influence of external factors, the room was relatively quiet. Each time before the start of the test, the platform was calibrated. These conditions allow for proper measurement, which is also characteristic of other studies [28, 29].

In the study using the ALFA platform, the load [%] of the right and left limbs on the 1st and 14th day of the rehabilitation process and the time of the dominant load [%] on the right and left limbs on the 1st and 14th day of the rehabilitation process were assessed.

Before starting the study, each of the patients gave written, voluntary consent to participate in the study, was informed about the purpose of the study, the use of the results for scientific purposes, and the possibility of resigning from participation in the study at any stage of its duration. The study did not bear any risk for the study participant. The study was performed in accordance with the Helsinki Declaration (WMA Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects).

Statistical analysis

Variables

The study assessed qualitative variables such as: place of residence, level of education, employment status, BMI as a qualitative variable, dominant limb, and limb after hip arthroplasty. Qualitative variables were presented using numbers and percentages.

Quantitative variables included in the analysis were age and BMI, as well as the number of points from the Harris Hip Score and WOMAC – HIP scales. The data analyzed from the Alfa platform measurements were: load on the right [%] and left limb [%] and load time [%] and symmetry index [%] compared between the 1st and 14th day of rehabilitation. The distribution of quantitative variables was presented using number, mean, median, minimum and maximum value, upper and lower quartile, and standard deviation.

Statistical inference

Statistical analysis of the collected material was carried out in the Statistica 13.1 program. The parametric and non-parametric tests were used to analyze the variables. The choice of the non-parametric test was conditioned by meeting its basic assumptions, i.e., the compliance of the distributions of the studied variables with the normal distribution, which was verified with the Shapiro-Wilk test. To assess the differences in the average level of the numerical variable in more than two populations, the Anova Kruskal-Wallis test was used. In the presence of statistically significant dependencies, the analysis was continued with the post-hoc test, which in this case was the multiple comparisons test. The Wilcoxon test was used for tw dependent variables. The main goal of the statistical analysis is to compare dependent ariables: parameters on the 1st and 14th day of rehabilitation. The level of statistical significance was $p < 0.05$.

Results

In the group of patients, a functional assessment of the hip joint was performed using a standardized tool – Harris Hip Score. The functional assessment of the hip joints of the studied patients was carried out on the 1st and 14th day of rehabilitation. The change in the functional status of the studied patients in the next two measurements, by an average of 8.57 points ± 6.56 points, was statistically significant ($p < 0.001$) (Table 2).

Table 2. Functional assessment of the hip joint according to the Harris Hip Score on the 1st and 14th day of rehabilitation performed in the study group of patients

Harris Hip Score [0–100 points]	Values							
	n	M	Me	Min.	Max.	Q1	Q3	SD
1st day of rehabilitation	44	64.51	63.69	33.30	91.00	51.30	74.39	14.95
14th day of rehabilitation	44	73.07	72.84	45.00	91.30	64.06	84.65	12.57
Differences	44	8.57	7.79	-0.30	23.75	2.64	14.40	6.56
p	p < 0.001							

N – number of observation; M – average; Me – median; Min – minimum; Max – maximum; Q1 – lower quartile; Q3 – upper quartile; SD – standard deviation; p – level of significance of differences

The functional assessment of the studied patients was also performed by presenting the results of the Harris Hip Score in a qualitative scale. In the measurement on the 1st day of rehabilitation, the functionality of the hip joint was assessed as poor by most patients (N = 27; 61.4%). After fourteen days of rehabilitation, the number of patients with poor assessment decreased to 16 (36.4%). Whereas, the number of patients whose functionality was assessed as satisfactory (from 20.5% to 31.8%) and good (from 11.4% to 25.0%) increased. These changes were statistically significant ($p < 0.001$) (Figure 1).

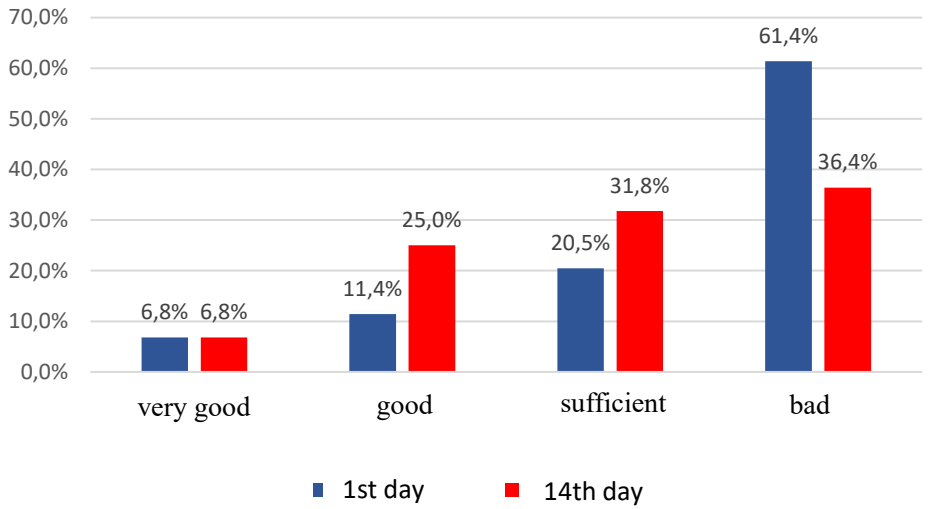

Figure 1. Functional assessment of the mentioned hip joint in the studied patients according to the Harris scale on the 1st and 14th day of rehabilitation presented in a qualitative form

Statistical analysis showed that the final functional assessment of the hip joint according to the Harris Hip Score significantly differed among the studied patients depending on the time that had passed since the surgery ($p = 0.031$). The mean time since surgery was compared in four groups of patients, based on their scores in the final Harris Hip Score.

There was a statistically significant difference between the time elapsed since the surgery in the case of people rated very good and bad on the functional scale ($p = 0.029$). In the case of people with a poor assessment, the time from the alloplastic procedure to the study was the shortest (approximately 4.63 months), and in the case of those with a very well rating, it was the longest (approximately 10.67 months) (Table 3).

Table 3. Assessment of the relationship between the final score of the studied patients on the Harris Hip Score scale and the time elapsed since the last surgery

Hip function assessment according to the Harris Hip Score	Values							
	n	M	Me	Min.	Max.	Q1	Q3	SD
Very good	3	10.67	11.00	9.00	12.00	9.00	12.00	1.53
Good	11	6.00	5.00	3.00	12.00	5.00	6.00	2.49
Sufficient	14	5.50	4.50	3.00	12.00	4.00	7.00	2.59
Bad	16	4.63	4.00	1.00	11.00	3.00	7.00	3.03
p	0.031							
	Qualitative assessment of the functionality of the mentioned hip joint							
post-hoc	Very good		Good		Sufficient		Bad	
Very good			0.447		0.151		0.029	
Good	0.447				1.000		0.713	
Sufficient	0.151		1.000				1.000	
Bad	0.029		0.713		1.000			

N – number of observation; M – average; Me – median; Min – minimum; Max – maximum; Q1 – lower quartile; Q3 – upper quartile; SD – standard deviation; p – level of significance of differences

The functional status of the studied patients was assessed using the WOMAC scale on the 1st and 14th day of rehabilitation. The result obtained by the subjects in the measurement on the 1st day was an average of 84.59 points ± 10.04 points, and on the 14th day of rehabilitation it decreased to an average of 74.92 points ± 14.03 points. The obtained change in the functional status of the studied patients in the next two measurements, by an average of 9.67 points ± 6.76 points, was statistically significant ($p < 0.001$) (Table 4).

Table 4. Assessment of the functional status of the studied patients according to the WOMAC scale on the 1st and 14th day of rehabilitation presented in quantitative form

WOMAC [%]	Values							
	n	M	Me	Min.	Max.	Q1	Q3	SD
1st day of rehabilitation	44	84.59	88.03	56.25	95.84	79.17	92.71	10.04
14th day of rehabilitation	44	74.92	77.61	39.59	93.75	68.43	85.42	14.03
Differences	44	9.67	10.42	16.66	2.09	10.74	7.29	-3.99
p	$p < 0.001$							

n – number of observation; M – average; Me – median; Min – minimum; Max – maximum; Q1 – lower quartile; Q3 – upper quartile; SD – standard deviation; p – level of significance of differences

On the basis of the study on the ALFA platform, the symmetry of the load on the lower limbs was assessed in the study group of patients on the 1st and 14th day of rehabilitation. The results obtained on the 1st day of rehabilitation indicated a greater average load on the right side (51.57% ± 5.75%) than on the left side (48.43% ± 5.75%), as well as a longer period of dominant load on the right side (60.41 ± 44.73%) than the left side (39.59% ± 44.73%). Subsequently, the load symmetry on the lower limbs was assessed in the measurement on the 14th day of rehabilitation. The obtained results also indicated a slightly higher average load on the right side (50.2% ± 2.81%) as well as a longer period of dominant load on the right side (50.34% ± 33.23%) (Table 5).

Table. 5. Presentation of the test results on the stabilometric platform on the 1st and 14th day of rehabilitation

Variables	Values							
	n	M	Me	Min.	Max.	Q1	Q3	SD
Measurement on the 1st day								
Load P [%]	44	51.57	52.50	41.00	71.00	47.00	55.00	5.75
Load L [%]	44	48.43	47.50	29.00	59.00	45.00	53.00	5.75
Time P [%]	44	60.41	93.00	0.00	100.00	3.00	100.00	44.73
Time L [%]	44	39.59	7.00	0.00	100.00	0.00	97.00	44.73
Measurement on the 14th day								
Load P [%]	44	50.20	50.00	43.00	57.00	49.00	51.00	2.81
Load L [%]	44	49.80	50.00	43.00	57.00	49.00	51.00	2.81
Time P [%]	44	50.34	51.00	0.00	100.00	20.50	77.00	33.23
Time L [%]	44	49.66	49.00	0.00	100.00	23.00	79.50	33.23

n – number of observation; M – average; Me – median; Min – minimum; Max – maximum; Q1 – lower quartile; Q3 – upper quartile; SD – standard deviation; P – right side; L – left side; Time P – time of the dominant load on the right side; Time L – time of the dominant load on the left side

The analysis of differences in the study on the stabilometric platform between the 1st and the 14th day of rehabilitation showed that both the average load on the right and left limbs decreased by an average of 1.36% ± 4.7%. Changes in the dominant load time of the limbs are similar, which in the case of both limbs decreased on average by 10.07% ± 45.68%. Statistical significance was not found for neither of the analyzed parameters (Table 6).

Table 6. Presentation of the results of the test on the platform on the 1st and 14th day of rehabilitation of the lower limb under recent surgery for the average load on the limb under surgery (a). for the average time of dominant load on the limb under surgery (b) and the assessment of load symmetry and time symmetry of load on the right and left limbs (c)

	Values								p
	n	M	Me	Min.	Max.	Q1	Q3	SD	
(a) Load [%]									
1st day of rehabilitation	44	45.34	46.00	29.00	55.00	44.00	47.50	3.65	<0.001
14th day of rehabilitation	44	49.02	50.00	43.00	56.00	48.00	50.00	2.64	
Differences	44	-3.68	-4.00	-14.00	-1.00	-4.00	-2.50	1.01	
(b) Time of dominant load [%]									
1st day of rehabilitation	44	7.95	1.00	0.00	100.00	0.00	6.50	17.39	<0.001
14th day of rehabilitation	44	38.07	38.50	0.00	100.00	8.50	54.00	30.96	
Differences	44	-30.12	-37.5	0.00	0.00	-8.50	-47.50	-13.57	
(c) Symmetry index [%]									
Load in 1 day	44	9.77	9.00	2.00	42.00	6.00	12.00	6.67	p < 0.001
Load on the 14th day	44	3.50	2.00	0.00	14.00	0.00	4.00	4.38	
Time in 1 day	44	88.64	98.00	16.00	100.00	89.00	100.00	20.16	p < 0.001
Time in day 14	44	55.23	59.00	0.00	100.00	21.00	90.00	35.99	

n – number of observation; M – average; Me – median; Min – minimum; Max – maximum; Q1 – lower quartile; Q3 – upper quartile; SD – standard deviation; p – level of significance of differences

A statistically significant difference was found between the mean load on the lower limb under recent surgery on the 1st day of rehabilitation and on the 14th day ($p < 0.001$). The mean load on the limb under surgery on the 1st day of rehabilitation was 45.34% ± 3.65%, and after 14 days it was 49.02% ± 2.64%. The obtained change indicates that the average load on the limb under surgery approached the middle value (50.0%) after the applied treatment.

The presence of a statistically significant difference between the mean dominant load time of the lower limb under recent surgery on the 1st and 14th day of rehabilitation was also confirmed ($p < 0.001$). The mean dominant load time on the limb under surgery was 7.95% ± 17.39% on the 1st day of rehabilitation, and 38.07% ± 30.93% on the 14th day.

The load symmetry index of the right and left lower limbs was also assessed for each of the subjects separately. The difference between the average load on the right and left limbs measured on the 1st day of rehabilitation was on average 9.77% ± 6.67% among all the subjects. On the 14th day of rehabilitation, the difference between the average load on the right and left limbs decreased to an average of 3.5% ± 4.38%. The change was statistically significant ($p < 0.001$).

Similarly, the symmetry index of the dominant loading time of the right and left lower limbs was assessed for each of the subjects separately. The difference between the mean dominating load time of the right and left limbs on the 1st day of measurement was on average 88.64% ± 20.16% among all the subjects. On the 14th day of rehabilitation, the difference between the dominant load time of the right and left limbs decreased to an average of 55.23% ± 35.99%. The change was statistically significant ($p <0.001$).

Discussion

Hip arthroplasty is a procedure after which the patient's recovery depends on many factors, such as the gait pattern, and the alleviation or elimination of the ailments of the factors. Pre- and post-surgery rehabilitation has an important role, which is to aid in regaining the correct range of motion of the limbs, increasing muscle strength, reducing pain [5, 30]. The quality of life is also important in this aspect, which includes not only the assessment of the patient's physical sphere, but also the mental sphere.

Individually modified physiotherapy program introduced before the surgery and its continuation in the post-surgery period create optimal conditions for patients to regain their fitness and independence in movement. Early activation of the patient, verticalization and re-education of gait are able to

significantly reduce the risk of complications resulting from akinesia, as well as the arthroplasty itself [5].

Rehabilitation is a very important element of treatment and should be aimed at the rapid return of the patient to fitness in performing everyday activities, as well as at the possible undertaking of a selected form of physical activity in the future [31]. In order for the return to physical activity to be safe, the patient should be subjected to comprehensive rehabilitation. As explained by Howard-Wilsher et al. [32], there is a need to develop and disseminate rehabilitation services in order to help the patient recover as soon as possible. Well-organized, structured rehabilitation interventions can lead to savings as well as cost reductions in other health care services [33, 34].

It is widely believed that the time of return of patients to activity should occur on average after 3–6 months [35], while some researchers believe that the joint after the surgery becomes efficient only after a year [20]. Liem [31] indicates that people who improved after hip arthroplasty achieve much better golf results than those who did not use rehabilitation. Extending the time of returning to physical activity allows the patient to improve muscle strength, range of motion, balance and coordination, control of the correct gait pattern, without increasing the risk of pain, dislocations, loosening of the prosthesis, or other complications. If the necessary conditions are met, the patient can safely start participating in physical activity. However, the date of commencement of physical activity should always be selected individually, according to the capabilities and predispositions [20, 35].

In many countries, an important element of comprehensive therapy is the inclusion of pre-surgery rehabilitation [10, 19, 23, 24, 36, 37], the aim of which is primarily to shorten the time of convalescence and hospital stay. Numerous studies have been conducted to assess the effectiveness of pre-surgery exercises among patients awaiting knee or hip arthroplasty surgery. Studies have shown that patients with a higher level of performance have a lower rate of post-surgery complications, show better functional results, and recover faster after arthroplasty [10, 34, 36, 38, 39, 40].

German scientists conducted analyses of opinions and recommendations regarding the therapy of people undergoing alloplasty among rehabilitation

specialists in Germany. Most specialists recommended increasing muscle strength and equalizing soft tissue tension before and after the surgery [36]. The important role of introducing comprehensive physiotherapeutic improvement in the early post-surgery period in patients undergoing hip arthroplasty is also emphasized by Yogi et al. By examining muscle strength, quality of life of patients several times and testing functionality within one year after total alloplasty, it was found that the greatest functional losses occur in the first month after the surgery [41]. This proves the need to plan and undertake rehabilitation activities as soon as possible after the surgery, and preferably before its application [10, 19, 24, 36, 37, 41]. Own study showed that none of the patients benefited from pre-surgery rehabilitation, while all respondents declared that after leaving the hospital they followed the recommendations provided by the physiotherapist.

In own study, the group of patients underwent a two-week rehabilitation process, which included: Rail – Continuous Passive Motion (CPM), isometric exercises of the lower limb muscles, learning to walk (usually on a treadmill) with step length analysis, kinesiotherapy – guided or other exercises depending on the period and cryotherapy.

The analysis of the obtained results showed that the patients were characterized by an improvement in the functionality of the lower limbs and an improvement in the symmetry of limb loading on the last day of the rehabilitation.

Similar conclusions were obtained in the studies by Demczyszak et al. [21]. Researchers demonstrated the effectiveness of the rehabilitation program in patients after cement arthroplasty of the hip joint. The study included 30 patients aged 61–80 years. Each patient underwent goniometric measurements of the range of motion in the hip joints before the surgery and after rehabilitation. The patients under surgery were included in a rehabilitation program, which consisted of anticoagulant prophylaxis, isometric exercises of the quadriceps muscle, active slow and relieved exercises, and exercises using the CPM splint for 30 minutes a day [21].

Many authors tried to assess the functional status and quality of life of patients after hip arthroplasty [2, 3, 5, 6, 8, 15, 21, 23, 42, 43]. In own study,

the HHS and WOMAC scales were used to functionally assess patients in the early period after hip arthroplasty on the 1st and 14th day of the rehabilitation program. These scales allowed to assess the most important aspects of patients' functioning in everyday life.

In the studies of Szczepłek et al., conducted at the Clinical Hospital in Otwock, patients obtained an average of 37.07 points in the Harris Hip Score, which is a poor result in relation to the norm. After the surgery, this result increased to an average level and amounted to 74.93 points. The improvement resulting from surgical treatment was statistically significant [43]. However, in the studies performed among patients of the Department of Trauma and Orthopedic Surgery at the Specialist Hospital in Szczecin-Zdunów, it was noted that patients after hip replacement surgery were characterized by a functional state similar to that before the surgery. However, the researchers suggested that in subsequent days of rehabilitation, a significant improvement in functional status should be expected [5].

The above thesis was confirmed in own study. The change in the functional status of the studied patients in the Harris Hip Score in the next two measurements was statistically significant and increased from 64.51 to 73.07 points, i.e., it improved by an average of 8.57 points. This proves the effectiveness of the applied therapeutic treatment and its positive impact on the quality of life of patients after hip arthroplasty. In addition, in own study, the functionality of the hip joint was assessed poorly by the majority of patients (64.4%) when measured before the surgery, while after implantation of the endoprosthesis, the number of patients with poor assessment decreased to 36.4%. Whereas, the number of patients whose functionality was assessed as satisfactory (from 20.5% to 31.8%) and good (from 11.4% to 25.0%) increased.

The analysis of the results obtained in own study using the WOMAC scale on the 1st and 14th day of rehabilitation showed a statistically significant change in the functional status of the studied patients in the next two measurements, on average by 9.67 points. Patients in the first measurement scored an average of 84.59 points, and on the 14th day of rehabilitation – an average of 74.92 points. In the studies by Szczepłek et al., patients scored

61.7 points on the WOMAC scale before the surgery, while after the surgery the WOMAC score statistically improved to an average of 19.78 points. The improvement in the condition of patients assessed using the WOMAC scale was at an average level of 42.44 points [43].

In the course of own study, high values of the BMI index were recorded, persisting above the norm in as many as 77% of the respondents. The body weight of the respondents ranged from 55 kg to 105 kg, and the respondents weighed an average of 75.95 kg. Similar results were also obtained by other authors [5, 42, 43, 44, 45, 46]. According to some researchers, overweight and obesity are one of the factors predisposing to the development of osteoarthritis [45, 46]. Studies performed by Harris et al. and Derman et al. have shown a correlation between the increase in BMI in the population in recent years and the growing number of patients undergoing hip surgery [45, 46].

As surgical techniques progress, alloplastic procedures are performed with greater sparing of soft tissues around the operated joint. In addition, progress in the field of implant production allows for more and more accurate reconstruction of normal anatomical and biomechanical conditions in the hip joint. This translates into improved parameters in the process of maintaining balance by a person undergoing surgery [47, 48, 49].

Studies performed by Yogi et al. showed that balance exercises added to a typical outpatient physiotherapy program resulted in a much greater improvement in balance in participants after total hip arthroplasty or total knee arthroplasty, compared to a typical exercise program alone. Physiotherapists may consider the use of equivalent exercises to improve balance in people in the acute post-surgery phase after total hip arthroplasty [41]. This will prove that the use of a comprehensive improvement process considering sensorimotor training and biofeedback has a positive effect on the symmetry of limb loading, which was also confirmed by the results of own study. The use of various stabilometric platforms to assess the reaction of ground forces such as ALPHA or Zebris-PDM-L allows for an advanced and objective assessment of all posturographic parameters in various study groups, both among sick and healthy people [50].

On the basis of the study on the ALFA platform, the symmetry of the load on the lower limbs was assessed in the study group of patients on the 1st and 14th day of rehabilitation. The average load on the limb under surgery on the 1st day of rehabilitation was 45.34%, and after 14 days the average load was 49.02%. The obtained change in the load on the operated limb indicates an improvement in the symmetry of limb loading after the applied rehabilitation. In own study, the difference between the load of the right and left limbs in the measurement on the 1st day of rehabilitation was on average at 9.77%, while on the 14th day of rehabilitation, the difference between the average load of the right and left limbs decreased to an average of 3.5%. The obtained change also indicates an improvement in the symmetry of limb loading.

Skiba et al. performed studies on the process of maintaining balance in patients with osteoarthritis of the hip joints in a standing position. The conducted analyses proved that patients with osteoarthritis are characterized by higher values of parameters than people after implantation of the endoprosthesis. These results suggest that maintaining a stable posture is easier in patients after total hip arthroplasty [49].

Properly selected and comprehensive pre- and post-surgery rehabilitation perform a very important role in the patient's recovery. For the patient, it is extremely important to improve efficiency in performing basic everyday activities, improve well-being, and improve the quality of life.

Limitation

The main aim of the study was to assess how 14-day rehabilitation after the surgery affects the degree of relief of the lower limbs, which is the main goal of rehabilitation after hip joint replacement. However, the earlier after surgery, the greater the disproportion in the load on the lower limbs. This causes a large discrepancy in the results and possible limitations in the analyses.

The studies did not analyze the degree of pain experienced or other factors that may directly or indirectly influence the outcome of rehabilitation, such as fear or depression.

The alpha platform used in the research is a static platform and tests proprioception poorly, especially when it comes to the hip joint, which may be a certain limitation when it comes to the comprehensive assessment of joint function. The platform allows for the assessment of parameters in static conditions, i.e., only when standing on both feet. Rather, it assesses the load on the affected limb and the healthy one and assesses the patient's overall balance and the change in these parameters as a result of the rehabilitation. Therefore, the main goal of the authors' research was not to evaluate rehabilitation and indicate its validity. The validity of the use of rehabilitation and its effectiveness is confirmed by many available scientific studies and this is an obvious evidence, which the authors do not intend to question. The introduction of a control group of healthy people is not applicable due to the main purpose of the research, which is to compare the 1st and last day of rehabilitation in terms of load on the lower limbs. In the group of healthy people, the norm is 50% load on the right and left lower limb.

The study and use of the alpha platform allowed us to assess how a 14-day rehabilitation program affects the load on the limbs. Due to the fact that one of the main goals of postoperative rehabilitation is to compensate for the load disproportion between the operated limb and the healthy limb, the main goal of the research was to compare the 1st and 14th day of rehabilitation and to verify stabilometric parameters and their changes in the musculoskeletal system during this period of rehabilitation.

Conclusions

1. The level of subjective assessment of the functionality of the operated hip joint in the examined patients increases after two weeks of rehabilitation, which is confirmed by the results of the Harris scale and the WOMAC-HIP scale.
2. The degree of load on the operated limb in the second measurement on the 14th day of rehabilitation is almost equal to the healthy limb. The 14-day rehabilitation process yields satisfactory therapeutic effects in patients after hip arthroplasty.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Biegański P, Polewska E. Choroba zwyrodnieniowa stawów biodrowych – pacjent i problemy funkcjonalne. Journal of Education, Health and Sport 2015; 5(8): 47–54.
2. Mariconda M, Galasso O, Costa GG, Recano P, Cerbasi S. Quality of life and functionality after total hip arthroplasty: a long-term follow--up study. BMC Musculoskelet Disord 2011 Dec.; 12(1): 222. https://doi.org/10.1186/1471-2474-12-222.
3. Padewski R, Szczypiór-Piasecka K, Antczak K, Mińko A. Evaluation of the functional condition of patients qualified for the treatment of hip alloplasty. Journal of Education, Health and Sport 2021 Sep.; 11(9): 663–677. https://doi.org/10.12775/JEHS.2021.11.09.082.
4. Romanowski W, Zdanowska A, Romanowski M. Choroba zwyrodnieniowa stawów – aktualne standardy leczenia. Rheumatology Forum 2016; 2(2): 52–57.
5. Sowa K, Kotwas A, Antczak K, Zdziarski K, Knyszyńska A, Karakiewicz B. Postępowanie rehabilitacyjne u pacjentów po endoprotezoplastyce stawu biodrowego w okresie szpitalnym jako profilaktyka przewlekłych deficytów funkcjonalnych. Pielęgniarstwo w Opiece Długoterminowej 2019; 1: 17–24.
6. Piekoszewska A, Kwiatkowski K. Evaluation of patients expectations connected with physical activity after hip arthroplasty. Advances in Rehabilitation 2013 Jan.; 27(4): 5–11. https://doi.org/10.2478/rehab-2014-0021.
7. Bojarczuk K, Lewicki M, Michalczak M, Smoleń A. Ocena stopnia natężenia odczuwanego bólu u pacjentów po endoprotezoplastyce stawu biodrowego przed i po operacji (Assessment of patients joint pain before and following total hip replacement surgery). Journal of Education,

Health and Sport 2016 Jan.; 6(6): 645–660. https://doi.org/10.5281/ZENODO.60775.

8. Ridan T, Ogrodzka K, Klis A. Postępowanie rehabilitacyjne po endoprotezoplastyce stawu biodrowego. Praktyczna Fizjoterapia i Rehabilitacja 2013; 43: 6–12.
9. Learmonth ID, Young C, Rorabeck C. The operation of the century: total hip replacement. The Lancet 2007 Oct.; 370(9597): 1508–1519. https://doi.org/10.1016/S0140-6736(07)60457-7.
10. Kamecka K, Rybarczyk-Szwajkowska A, Staszewska A, Engelseth P, Kozlowski R. Process of Posthospital Care Involving Telemedicine Solutions for Patients after Total Hip Arthroplasty. Int J Environ Res Public Health 2021 Sep.; 18(19): 10135. https://doi.org/10.3390/ijerph181910135.
11. Surgical Operations and Procedures Performed in Hospitals – Top 10 Procedures Group 1, 2020 (per 100,000 Inhabitants) Health2022.png. Retrieved from https://ec.europa.eu/eurostat/statisticsexplained/index.php?title=File:Surgical_operations_and_procedures_performed_in_hospitals_%E2%80%93_top_10_procedures_group_1,_2020_(per_100_000_inhabitants)_Health2022.png . Access: 30 December 2022.
12. Centralna Baza Endoprotezoplastyk Narodowego Funduszu Zdrowia. Realizacja Świadczeń Endoprotezoplastyki Stawowej w 2021 r. Retrieved from: https://www.nfz.gov.pl/o-nfz/publikacje/. Access: 30 December 2022.
13. The American Joint Replacement Registry Annual Report. Retrieved from: https://www.aaos.org/registries/publications/ajrr-annual-report/. Access: 30 December 2022.
14. Świtoń A, Wodka-Natkaniec E, Niedźwiedzki Ł, Gaździk T, Niedźwiedzki T. Activity and Quality of Life after Total Hip Arthroplasty. Ortop Traumatol Rehabil 2017; 19(5). https://doi.org/10.5604/01.3001.0010.5823.
15. Białkowska M et al. Quality of Life of Men after Cementless Hip Replacement – a Pilot Study. Ortop Traumatol Rehabil 2020 Jun.; 22(3): 161–171. https://doi.org/10.5604/01.3001.0014.3232.

16. Wengler A, Nimptsch U, Mansky T. Hip and Knee Replacement in Germany and the USA. Dtsch Arztebl Int 2014 Jun. https://doi.org/10.3238/arztebl.2014.0407.
17. Kamaruzaman H, Kinghorn P, Oppong R. Cost-effectiveness of surgical interventions for the management of osteoarthritis: a systematic review of the literature. BMC Musculoskelet Disord 2017 Dec.; 18(1): 183. https://doi.org/10.1186/s12891-017-1540-2.
18. Kheir M et al. Perioperative Telephone Encounters Should Be Included in the Relative Value Scale Update Committee Review of Time Spent on Total Hip and Knee Arthroplasty. J Arthroplasty 2019 Aug.; 34(8): 1563–1569. https://doi.org/10.1016/J.ARTH.2019.05.010.
19. Głodzik J. Postępowanie fizjoterapeutyczne w totalnej alloplastyce stawu biodrowego. Acta Scientifica Academiae Ostroviensis 2003; 13: 67–83.
20. Rosa E, Hagner W, Kazimierczak U, Srokowski G, Radzymińska A. Postępowanie rehabilitacyjne po wszczepieniu endoprotezy bezcementowej stawu biodrowego. Fizjoterapia Polska 2003; 3(2): 159–163.
21. Demczyszak I, Wrzosek Z, Żukowska U, Milko D. Ocena efektów usprawniania chorych po endoprotezoplastyce stawu biodrowego. Kwartalnik Ortopedyczny 2012; 2: 169–175.
22. Stolarczyk A, Deszczyński J, Barczyk K, Bugaj J, Nagraba Ł, Mitek T. Algorytm postępowania z pacjentem ze sztucznym stawem biodrowym lub kolanowym w aspekcie powrotu do pełnienia ról społecznych i zawodowych (adaptacji społecznej i zawodowej) – kontekst psychologiczno-psychoterapeutyczny. Artroskopia i Chirurgia Stawów 2011; 7(3): 62–73.
23. Kieszkowska-Grudny A, Maleszewska J, Siwy-Hudowska A, Nawrocki S. Ocena jakości życia i strategii radzenia sobie z chorobą w grupie chorych poddanych zabiegowi endoprotezoplastyki stawu biodrowego. Gerontologia Polska 2014; 2: 62–69.
24. Grochans S, Rachubińska K, Cybulska AM, Iżak WM. The quality of life in patients after hip endoprosthesis implementation. Pielęgniarstwo w Opiece Długoterminowej / Long-Term Care Nursing 2021; 6(2): 5–15.

25. Harris Hip Score (HHS). Retrieved from: https://www.codetechnology.com/blog/harris-hip-tool/. Access: 12 August 2023.
26. Jankowska-Polańska B, Polański J. Methods of evaluation of the quality of life in rheumatic diseases. Rheumatology 2014 Feb.; 52(1): 69–76. https://doi.org/10.5114/reum.2014.41453.
27. Matłosz P et al. Agreement of Three Posturographic Force Plates in the Assessment of Postural Stability. Int J Environ Res Public Health 2020 May; 17(9): 3188. https://doi.org/10.3390/ijerph17093188.
28. Sikora D, Pałac M, Myśliwiec A, Wolny T, Linek P. Assessment of the Relationship between Y-Balance Test and Stabilometric Parameters in Youth Footballers. Biomed Res Int 2020 Nov, 1–5. https://doi.org/10.1155/2020/6968473.
29. Pop T et al. The Assessment of Static Balance in Patients after Total Hip Replacement in the Period of 2–3 Years after Surgery. Biomed Res Int 2018, 1–8. https://doi.org/10.1155/2018/3707254.
30. Vos T et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet 2012 Dec.; 380(9859): 2163–2196. https://doi.org/10.1016/S0140-6736(12)61729-2.
31. Liem D, Van Fabeck K, Poetzl W, Winkelmann W, Gosheger G. Golf after Total Hip Arthroplasty: A Retrospective Review of 46 Patients. J Sport Rehabil 2006 Aug.; 15(3): 205–215. https://doi.org/10.1123/jsr.15.3.205.
32. Howard-Wilsher S et al. Systematic overview of economic evaluations of health-related rehabilitation. Disabil Health J 2016 Jan.; 9(1): 11–25. https://doi.org/10.1016/j.dhjo.2015.08.009.
33. Snow R, Granata J, Ruhil AVS, Vogel K, McShane M, Wasielewski R. Associations Between Preoperative Physical Therapy and Post-Acute Care Utilization Patterns and Cost in Total Joint Replacement. Journal of Bone and Joint Surgery; 2014 Oct.; 96(19): e165. https://doi.org/10.2106/JBJS.M.01285.
34. Szilágyiné Lakatos T, Lukács B, Veres-Balajti I. Cost-Effective Healthcare in Rehabilitation: Physiotherapy for Total Endoprosthesis Surgeries from

Prehabilitation to Function Restoration. Int J Environ Res Public Health 2022; 19(22): 15067. https://doi.org/10.3390/ijerph192215067.

35. Jachimowicz-Wołoszynek D, Rość D, Michalska A. Wpływ wszczepienia sztucznego stawu biodrowego na jakość życia chorych z chorobą zwyrodnieniową stawu biodrowego. Ortop Traumatol Rehabil 2003; 5(4): 518–526.
36. Eulenburg C, Rahlf AL, Kutasow A, Zech A. Agreements and disagreements in exercise therapy prescriptions after hip replacement mong rehabilitation professionals: a multicenter survey. BMC Musculoskelet Disord 2015 Dec.; 16(1): 185. https://doi.org/10.1186/s12891-015-0646-7.
37. Szilágyiné Lakatos T, Lukács B, Veres-Balajti I. Cost-Effective Healthcare in Rehabilitation: Physiotherapy for Total Endoprosthesis Surgeries from Prehabilitation to Function Restoration. Int J Environ Res Public Health 2022 Nov.; 19(22): 15067. https://doi.org/10.3390/ijerph192215067.
38. Majid N, Lee S, Plummer V. The effectiveness of orthopedic patient education in improving patient outcomes: a systematic review protocol. JBI Database System Rev Implement Rep 2015 Jan.; 13(1): 122–133. https://doi.org/10.11124/jbisrir-2015-1950.
39. An J, Ryu HK, Lyu SJ, Yi HJ, Lee BH. Effects of Preoperative Telerehabilitation on Muscle Strength, Range of Motion, and Functional Outcomes in Candidates for Total Knee Arthroplasty: A Single-Blind Randomized Controlled Trial. Int J Environ Res Public Health; 2021 Jun.; 18(11): 6071. https://doi.org/10.3390/ijerph18116071.
40. Oosting E et al. Preoperative Home-Based Physical Therapy Versus Usual Care to Improve Functional Health of Frail Older Adults Scheduled for Elective Total Hip Arthroplasty: A Pilot Randomized Controlled Trial. Arch Phys Med Rehabil 2012 Apr.; 93(4): 610–616. https://doi.org/10.1016/j.apmr.2011.11.006.
41. Jogi P, Zecevic A, Overend TJ, Spaulding SJ, Kramer JF. Force-plate analyses of balance following a balance exercise program during acute post-operative phase in individuals with total hip and knee arthroplasty: A randomized clinical trial. SAGE Open Med 2016 Jan.; 4, 205031211667509. https://doi.org/10.1177/2050312116675097.

42. Pop T, Dudek J, Bielecki A, Dudek W, Snela S. Stan funkcjonalny chorych po endoprotezoplastyce stawu biodrowego pochodzących z terenów wiejskich. Przegląd Medyczny Uniwersytetu Rzeszowskiego 2011; 1: 9–89.
43. Szczepłek K, Truszczyńska-Baszak A, Twarowska NA. The influence of total hip arthroplasty on patients' disability. Advances in Rehabilitation 2018; 32(1): 31–37. https://doi.org/10.5114/areh.2018.76988.
44. Dziekońska M, Latosiewicz R, Kulikowska A. Pielęgnowanie pacjenta po endoprotezoplastyce stawu biodrowego. Hygeia Public Health 2013; 48(3): 355–359.
45. Harris EC, Coggon D. HIP osteoarthritis and work. Best Pract Res Clin Rheumatol 2015 Jun.; 29(3): 462–482. https://doi.org/10.1016/j.berh.2015.04.015.
46. Derman PB, Fabricant PD, David G. The Role of Overweight and Obesity in Relation to the More Rapid Growth of Total Knee Arthroplasty Volume Compared with Total Hip Arthroplasty Volume. Journal of Bone and Joint Surgery 2014 Jun.; 96(11): 922–928. https://doi.org/10.2106/JBJS.L.01731.
47. Wareńczak A, Lisiński P. Does total hip replacement impact on postural stability? BMC Musculoskelet Disord 2019; 20(1): 229. https://doi.org/10.1186/s12891-019-2598-9.
48. Majewski M, Bischoff-Ferrari HA, Grüneberg C, Dick W, Allum JHJ. Improvements in balance after total hip replacement. J Bone Joint Surg Br 2005 Oct.; 87-B(10): 1337–1343. https://doi.org/10.1302/0301-620X.87B10.16605.
49. Skiba G, Czerner M, Słonka K, Królińska M, Kiliański M, Krajczy M. Evaluation of some stabilography parameters in patients after Total alloplastics hip join. The Journal of Orthopaedics Trauma Surgery and Related Research 2007; 3(7): 41–47.
50. Krawczyk-Suszek M, Martowska B, Sapuła R. Analysis of the Stability of the Body in a Standing Position When Shooting at a Stationary Target – A Randomized Controlled Trial. Sensors 2022; 22(1): 368. https://doi.org/10.3390/s22010368.